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Andrade Dias et al.

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(54) **OPTIMIZED POWER MANAGEMENT FOR A TRANSPORT CLIMATE CONTROL ENERGY SOURCE**

(71) Applicant: **THERMO KING CORPORATION**, Minneapolis, MN (US)

(72) Inventors: **Marcelo Andrade Dias**, Lakeville, MN (US); **Ryan Wayne Schumacher**, Bloomington, MN (US); **Mark D. Leasure**, Eagan, MN (US); **Vikram Madineni**, Dusseldorf (DE); **Alexander Iglizn**, Essen (DE); **Matthias Gorski**, Bochum (DE)

(73) Assignee: **Thermo King Corporation**, Minneapolis, MN (US)

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CPC ***B60H 1/00428*** (2013.01); ***H02J 1/002*** (2020.01); ***H02J 3/322*** (2020.01);
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Primary Examiner — Harry R Behm
(74) *Attorney, Agent, or Firm* — Hamre, Schumann, Mueller & Larson, P.C.

(57) **ABSTRACT**

An optimized power converter for use in a transport electrical system that provides power to a transport climate control system is provided. The optimized power converter includes an optimized DC/DC converter and an inverter/active rectifier. The optimized DC/DC converter is only boosts a voltage level when current is directed from a rechargeable energy storage to the inverter/active rectifier and only bucks a voltage level when current is directed from the inverter/active rectifier to the rechargeable energy storage. In a charging mode, the inverter/active rectifier converts three phase AC power into DC power, and the optimized power converter bucks the DC power to a voltage level that is acceptable for charging the rechargeable energy storage. In a discharge mode, the optimized DC/DC converter boosts voltage from the rechargeable energy storage, and the inverter/active rectifier converts boosted DC power into

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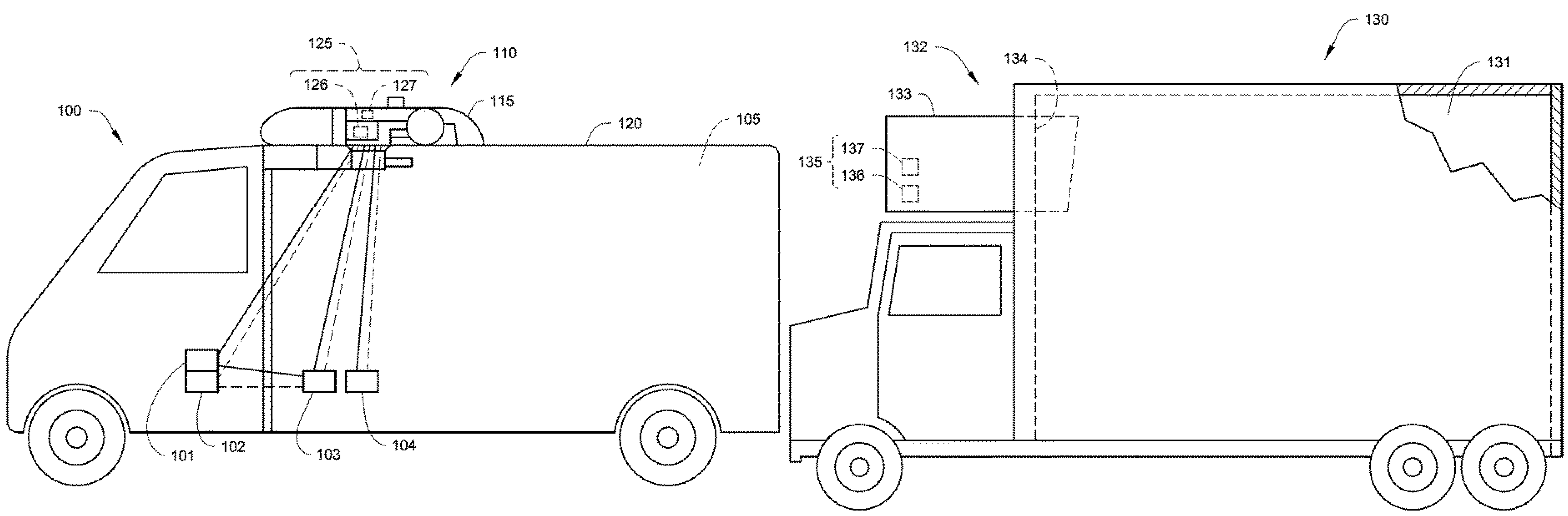

three phase AC power for powering a transport climate control system load.

20 Claims, 9 Drawing Sheets

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CPC H02M 1/007; B60H 1/00428; B60H 2001/3292
See application file for complete search history.

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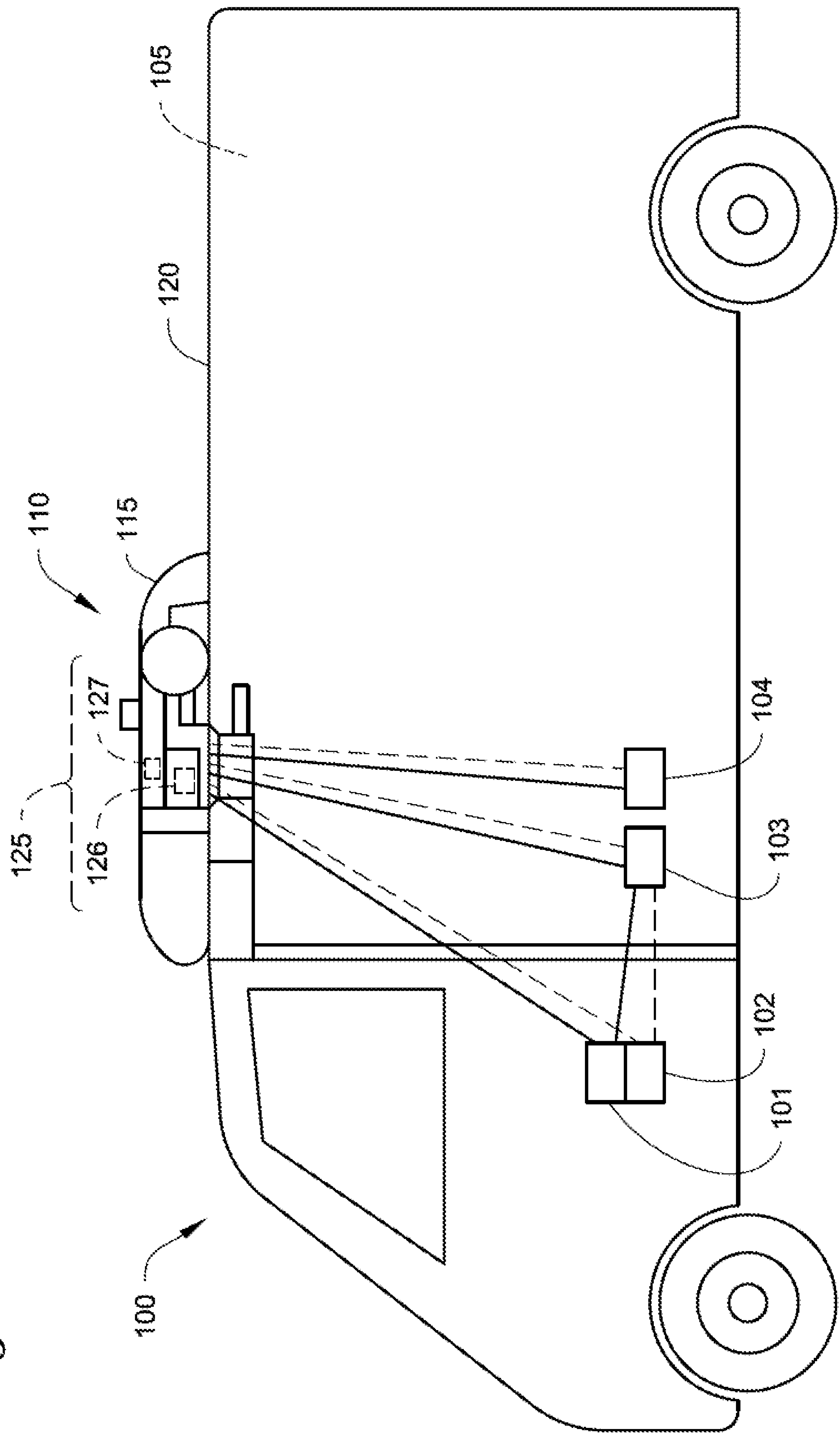

Fig. 1A

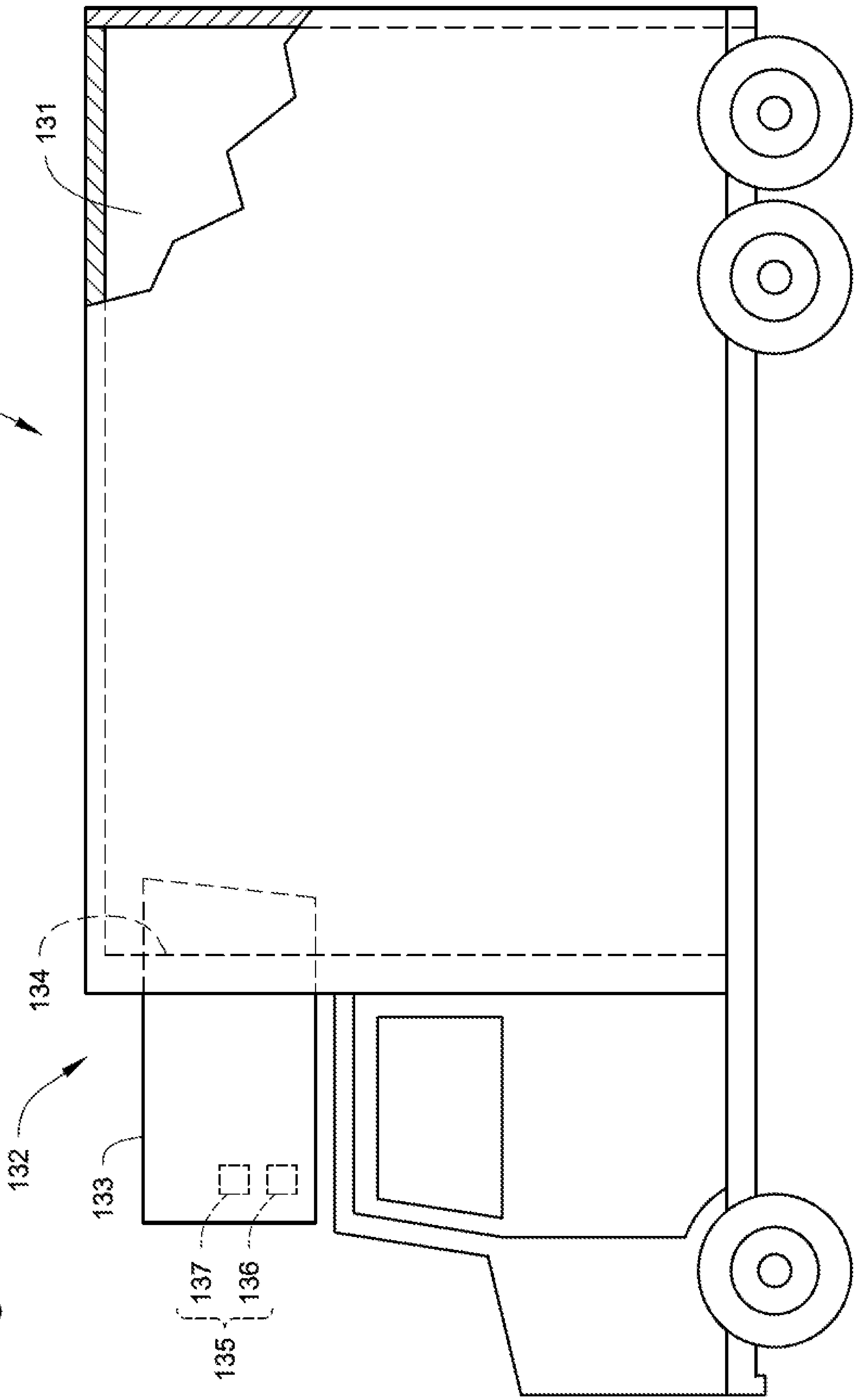

Fig. 1B

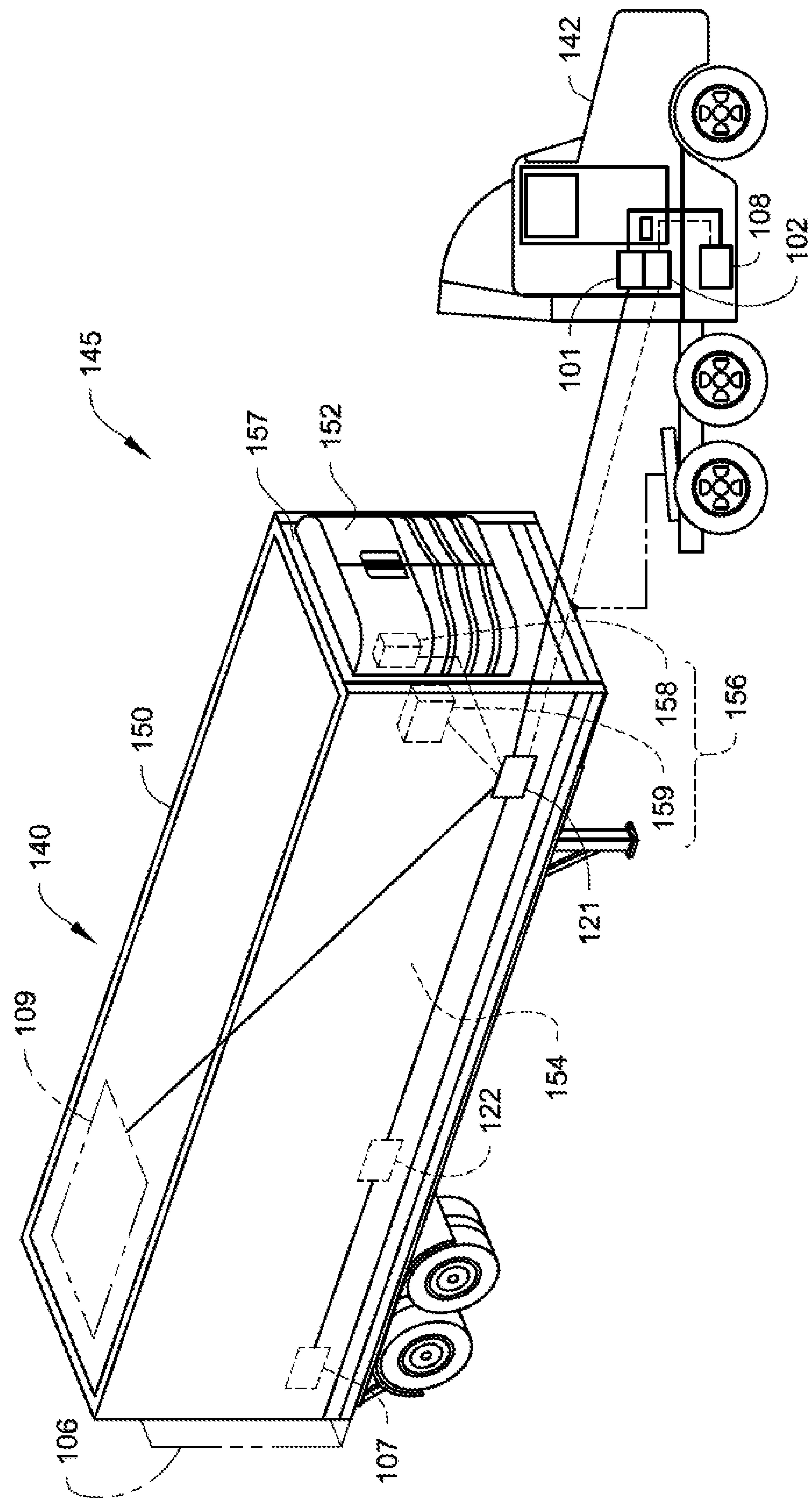
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Fig. 1C

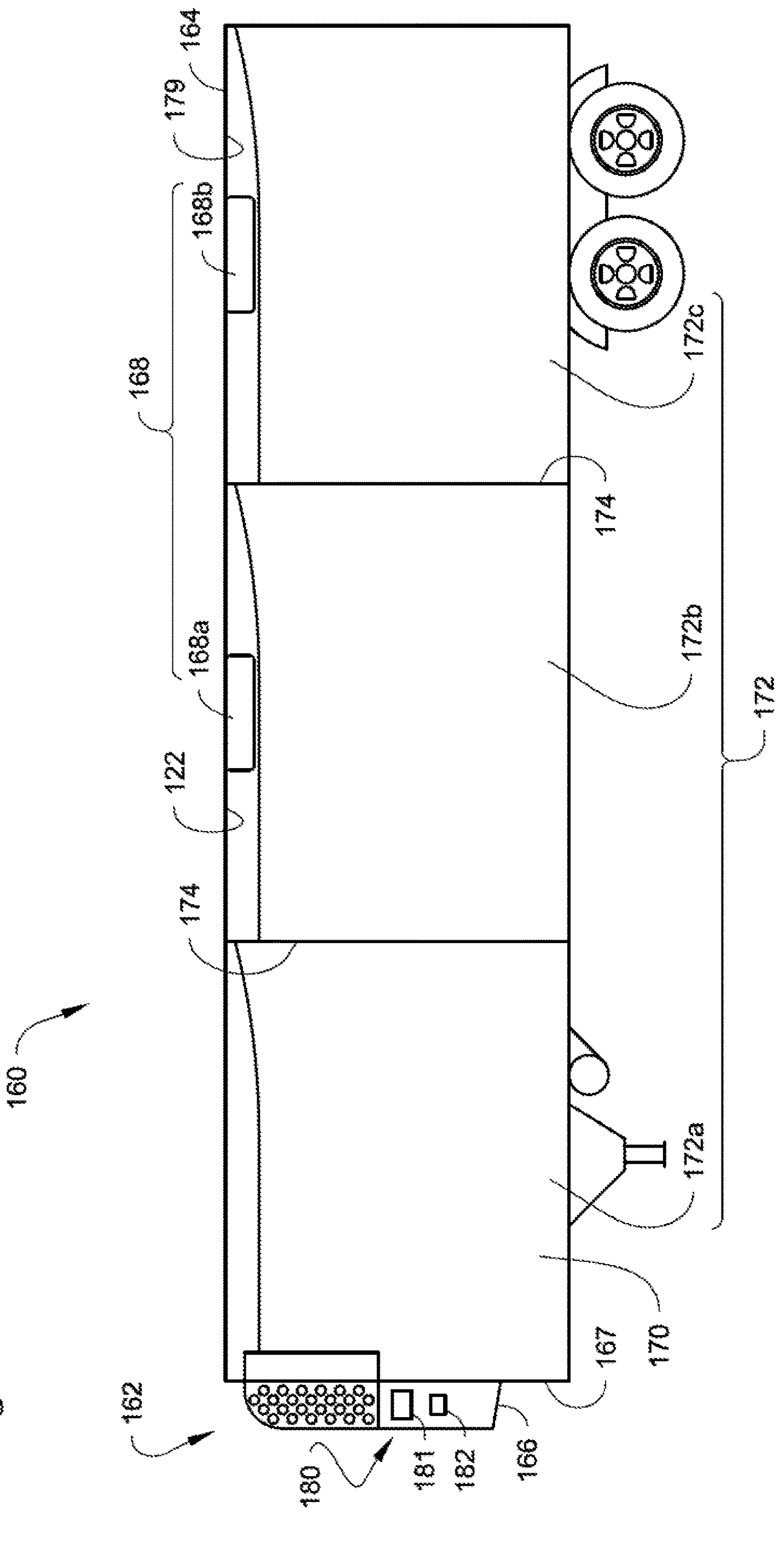
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Fig. 1D

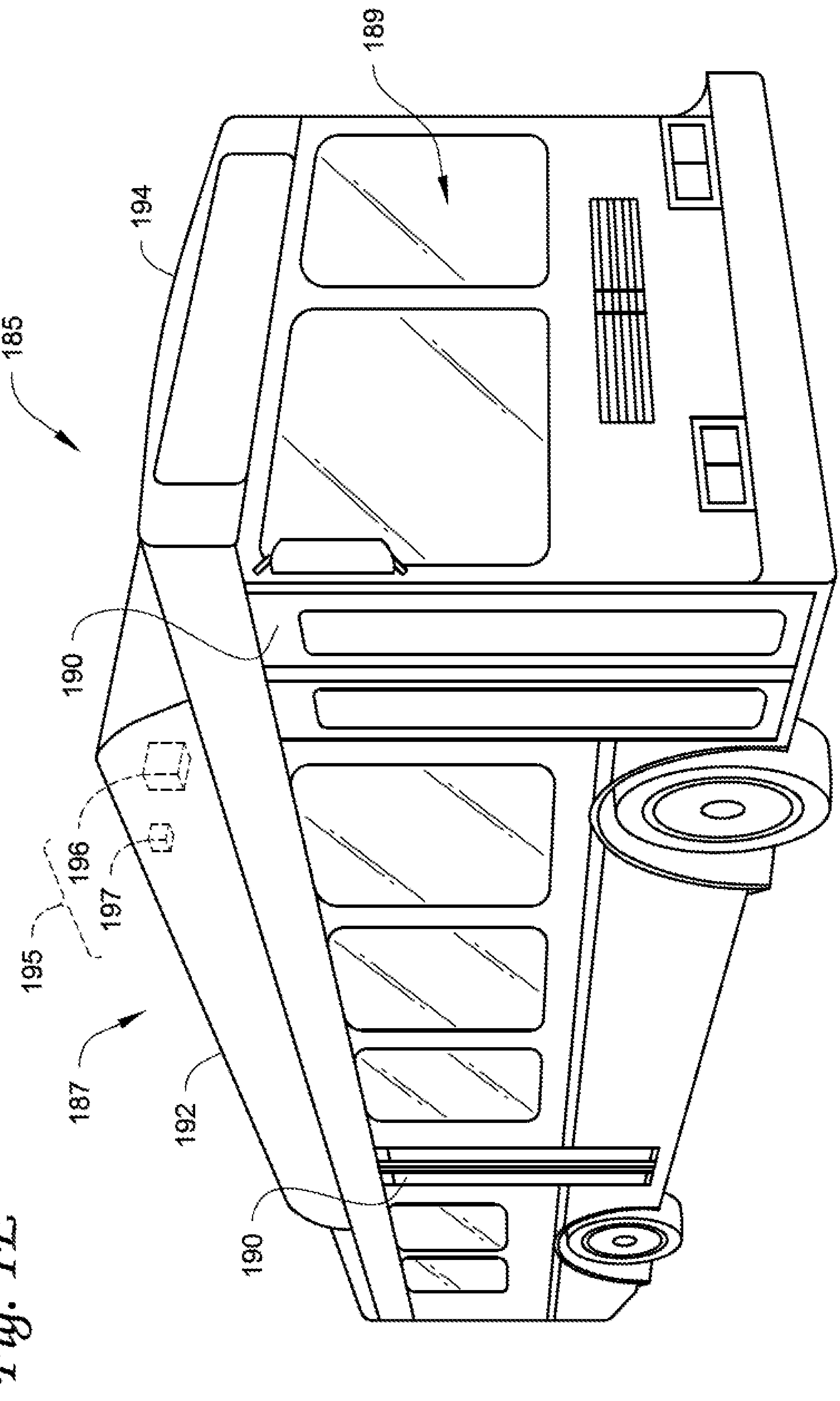
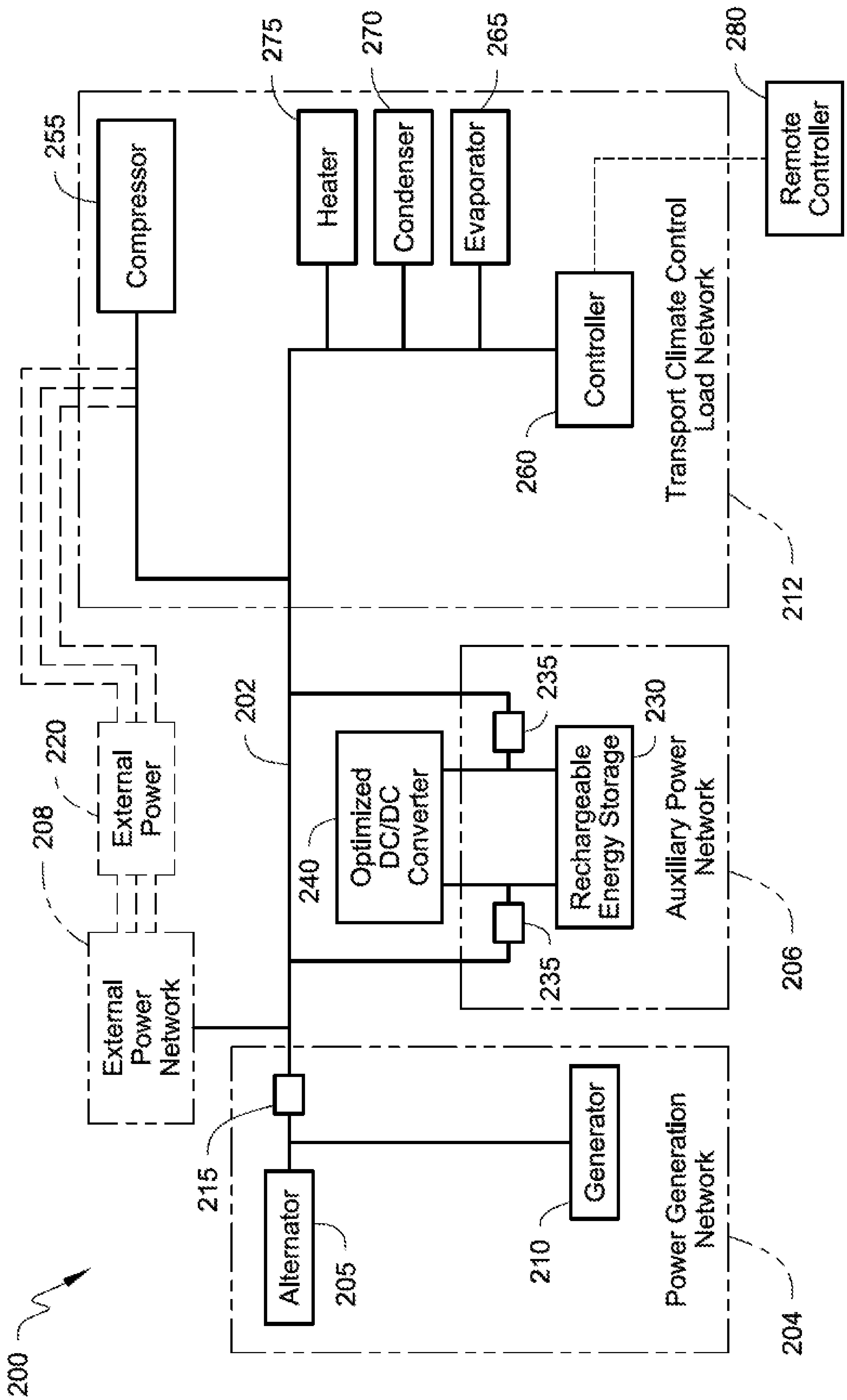


Fig. 1E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Compressor
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Heater
275
Condenser
270
Evaporator
265
Controller
260
Remote Controller
280
Transport Climate Control Load Network
212
External Power
220
External Power Network
208
202
Optimized DC/DC Converter
240
235
Rechargeable Energy Storage
230
235
Auxiliary Power Network
206
215
Alternator
205
Generator
210
Power Generation Network
204

Fig. 2

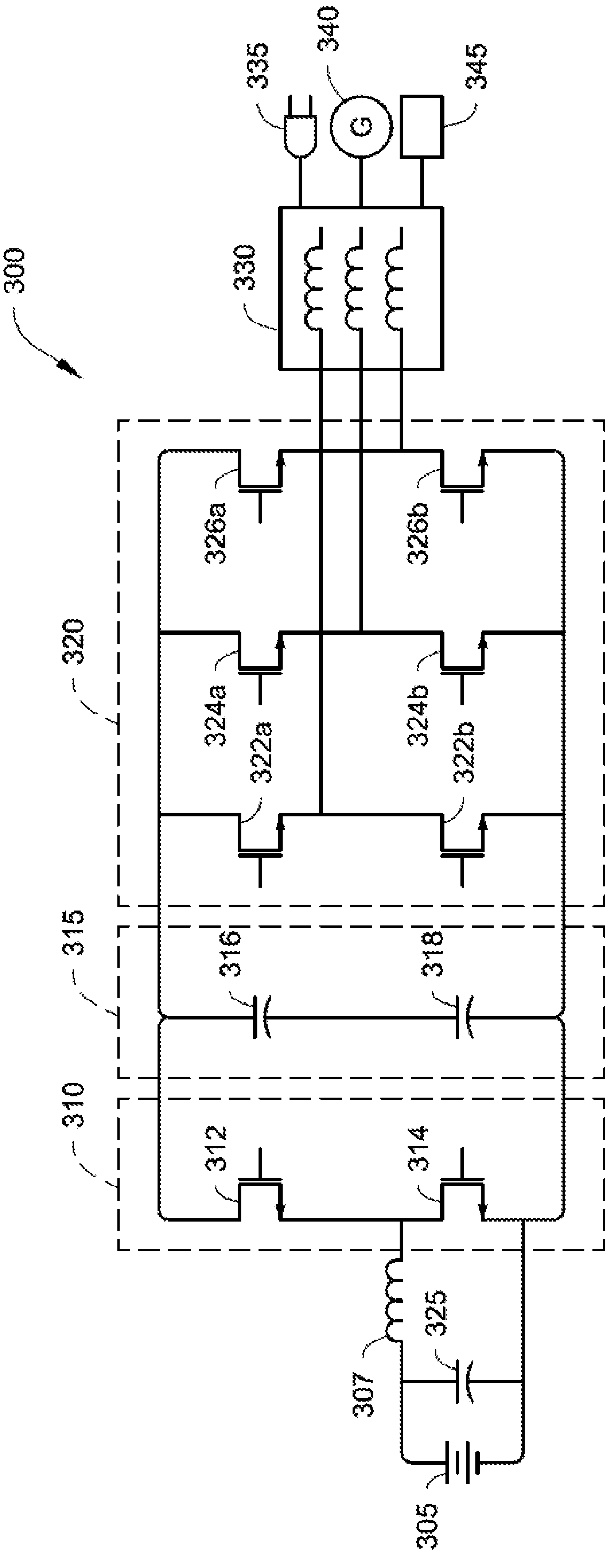
300
335
340
G
345
330
320
326a
326b
324a
324b
322a
322b
315
316
318
310
312
314
325
307
305

Fig. 3A

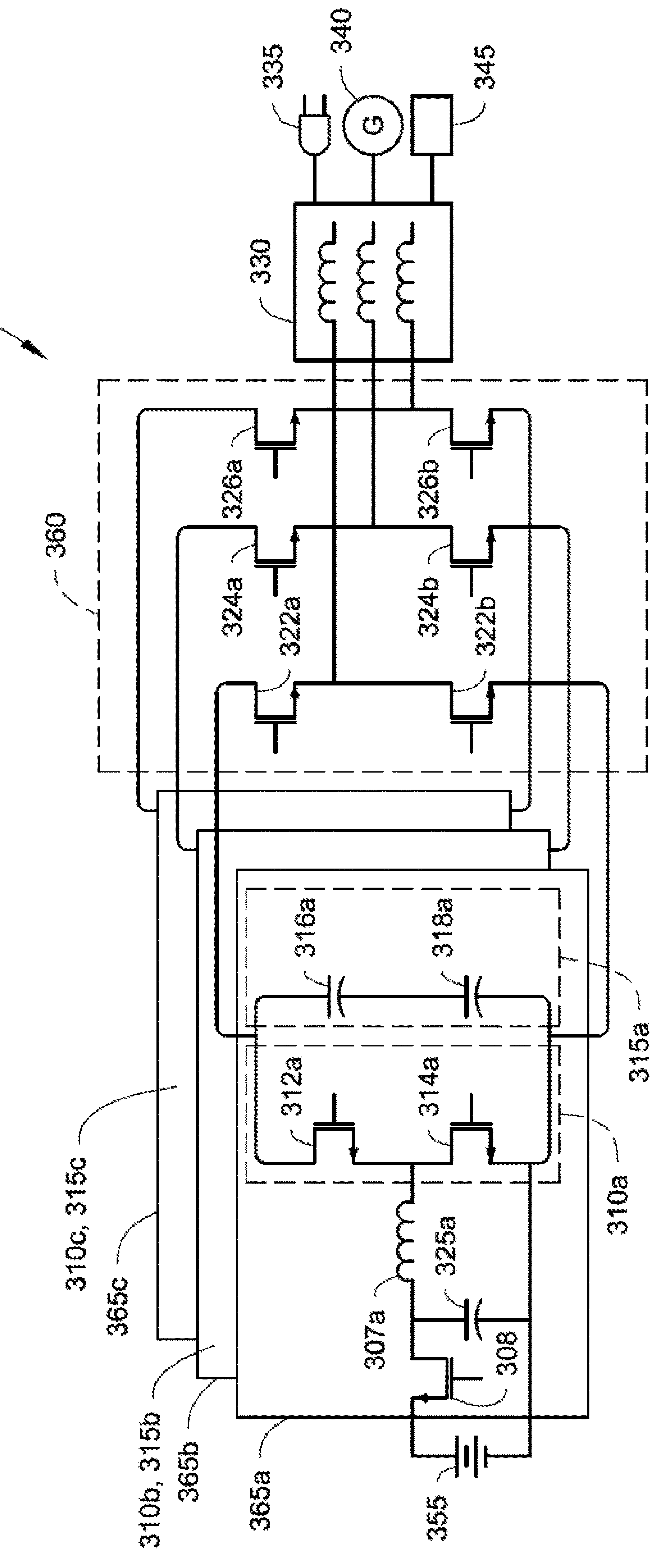
350
330
335
340
G
345
360
326a
326b
324a
324b
322a
322b
316a
318a
315a
312a
314a
310a
325a
307a
308
355
365a
365b
310b, 315b
365c
310c, 315c

Fig. 3B

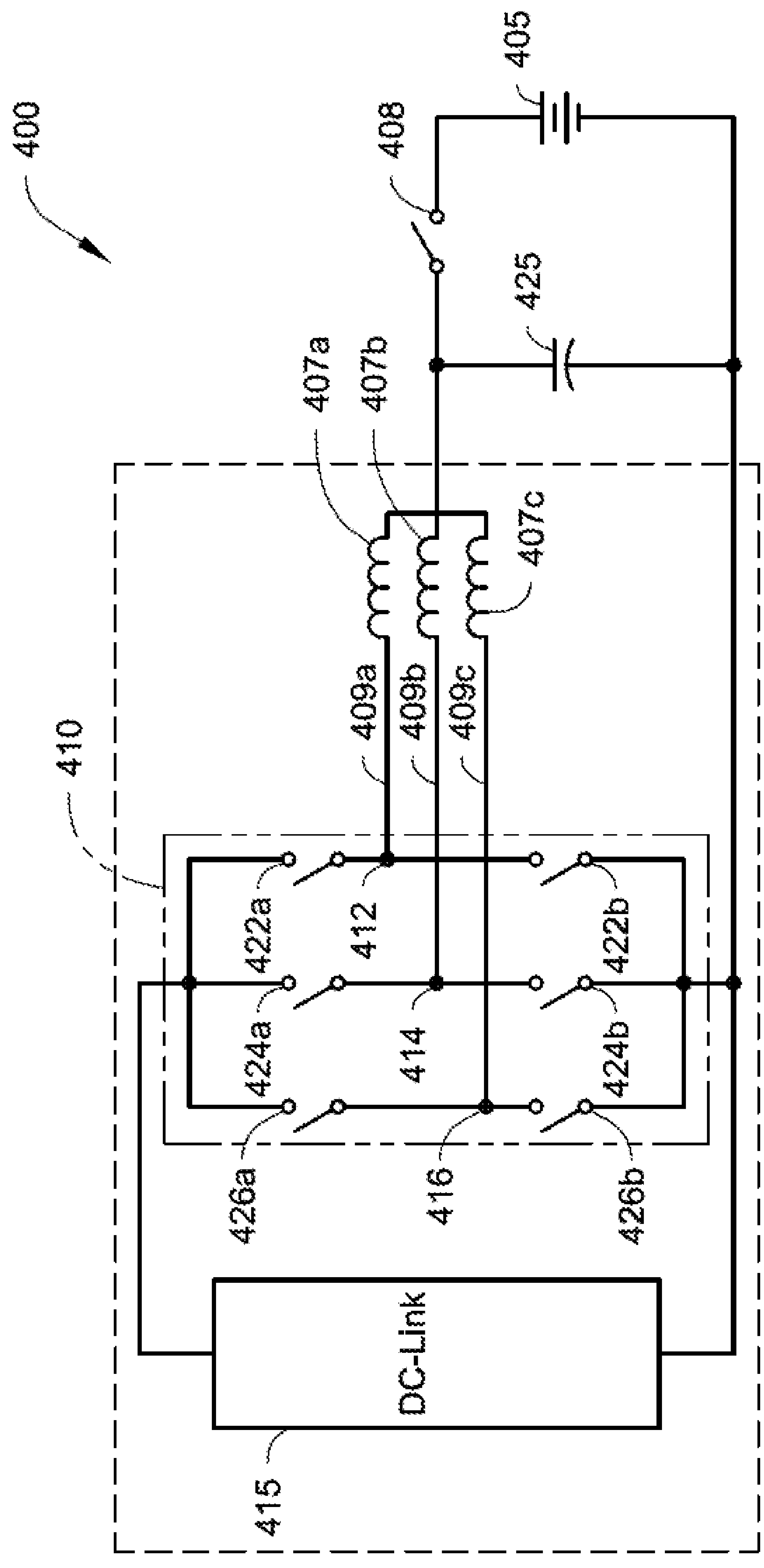
400
405
408
425
407a
407b
407c
409a
409b
409c
410
412
414
416
422a
422b
424a
424b
426a
426b
DC-Link
415

Fig. 4

OPTIMIZED POWER MANAGEMENT FOR A TRANSPORT CLIMATE CONTROL ENERGY SOURCE

FIELD

The disclosure herein relates to an electrically powered accessory configured to be used with at least one of a vehicle, trailer and a transport container. More particularly, the disclosure herein relates to optimized power management to control charge and discharge of a rechargeable energy storage used for powering the electrically powered accessory.

BACKGROUND

A transport climate control system is generally used to control environmental condition(s) (e.g., temperature, humidity, air quality, and the like) within a climate controlled space of a transport unit (e.g., a truck, a container (such as a container on a flat car, an intermodal container, etc.), a box car, a semi-tractor, a bus, or other similar transport unit). The transport climate control system can include, for example, a transport refrigeration system (TRS) and/or a heating, ventilation and air conditioning (HVAC) system. The TRS can control environmental condition(s) within the climate controlled space to maintain cargo (e.g., produce, frozen foods, pharmaceuticals, etc.). The HVAC system can control environmental conditions(s) within the climate controlled space to provide passenger comfort for passengers travelling in the transport unit. In some transport units, the transport climate control system can be installed externally (e.g., on a rooftop of the transport unit, on a front wall of the transport unit, etc.).

In some embodiments, the transport climate control system can be a multi-zone transport climate control system (MTCS). The MTCS can be used to separately and independently control environmental condition(s) within each of the multiple zones of the climate controlled space. The MTCS can include a host unit, and one or more remote units that may be provided in different locations of the transport unit for separate climate control within each of the zones. In some instances, the MTCS can have two or more remote units without a host unit.

SUMMARY

The embodiments disclosed herein relate to an electrically powered accessory configured to be used with at least one of a vehicle, trailer and a transport container. More particularly, the embodiments disclosed herein relate to optimized power management to control charge and discharge of a rechargeable energy storage device used for powering the electrically powered accessory.

In particular, the embodiments described herein can integrate charging and discharging of a transport climate control rechargeable energy storage in a single circuit. Generally, the rechargeable energy storage has a lower voltage than a Direct Current ("DC") link voltage (either powered from a generator/alternator controlled regeneration or an external power source (e.g., a utility power source, a commercial charging station, etc.) controlled by a front end converter). The embodiments described herein can provide an optimized DC/DC converter between the rechargeable energy storage and the DC link that is configured to boost voltage and limit current in a discharge mode of the rechargeable energy storage and buck voltage in a charging mode.

The embodiments described herein can also provide an optimized power converter that can alternatively operate in a charge mode and a discharge mode using a single DC/DC converter circuit based on a status of the transport climate control system and available power source options. In particular, a controller can provide pulse width modulation (PWM) control of switches of the single DC/DC converter circuit to provide only a voltage boost (step-up) in one direction of the single DC/DC converter circuit and only a voltage buck (step-down) in an opposite direction of the single DC/DC converter circuit. Accordingly, a rechargeable energy storage connected to the single optimized DC/DC converter circuit can be used more flexibility as the rechargeable energy storage voltage can be matched to the DC link regardless of the voltage at the DC link. That is, the embodiments described herein can allow for a universal rechargeable energy storage that can operate at multiple voltage levels via the optimized power converter. During the charging mode, the controller can modify (e.g., buck) the voltage level of a power source using PWM control to match an operating/state of charge voltage level of the rechargeable energy storage. During the discharge mode, the controller can modify (e.g., boost) the voltage level of the rechargeable energy storage using PWM control to match the voltage level at the DC link.

In one embodiment, an optimized power converter for use in a transport electrical system that provides power to a transport climate control system is provided. The optimized power converter includes an optimized DC/DC converter and an inverter/active rectifier. The optimized DC/DC converter is connected between a rechargeable energy storage of the transport electrical system that provides DC power and the inverter/active rectifier. The optimized DC/DC converter is configured to only boost a voltage level when current is directed from the rechargeable energy storage to the inverter/active rectifier and is configured to only buck a voltage level when current is directed from the inverter/active rectifier to the rechargeable energy storage. The inverter/active rectifier is connected to the optimized DC/DC converter. The optimized power converter is configured to operate in a charging mode and a discharge mode. When the optimized power converter is operating in the charging mode, the inverter/active rectifier is configured to convert three phase Alternating Current ("AC") power into DC power, and the optimized power converter is configured to buck the DC power to a voltage level that is acceptable for charging the rechargeable energy storage. When the optimized power converter is operating in the discharge mode, the optimized DC/DC converter is configured to boost voltage from the rechargeable energy storage, and the inverter/active rectifier is configured to convert boosted DC power into three phase AC power for powering one or more AC loads of the transport climate control system.

In another embodiment, a transport electrical system for powering a transport climate control system is provided. The transport electrical system includes a transport climate control load network and an optimized power converter. The transport climate control load network includes a plurality of transport climate control loads that use power to operate the transport climate control system. The optimized power converter provides power to one or more transport climate control loads of the transport climate control load network. The optimized power converter includes an optimized DC/DC converter and an inverter/active rectifier. The optimized DC/DC converter is connected between a rechargeable energy storage of the transport electrical system that provides DC power and an inverter/active rectifier. The

optimized DC/DC converter is configured to only boost a voltage level when current is directed from the rechargeable energy storage to the inverter/active rectifier and is configured to only buck a voltage level when current is directed from the inverter/active rectifier to the rechargeable energy storage. The inverter/active rectifier is connected to the optimized DC/DC converter. The optimized power converter is configured to operate in a charging mode and a discharge mode. When the optimized power converter is operating in the charging mode, the inverter/active rectifier is configured to convert three phase AC power into DC power, and the optimized power converter is configured to buck the DC power to a voltage level that is acceptable for charging the rechargeable energy storage. When the optimized power converter is operating in the discharge mode, the optimized DC/DC converter is configured to boost voltage from the rechargeable energy storage, and the inverter/active rectifier is configured to convert boosted DC power into three phase AC power for powering the one or more transport climate control loads.

In yet another embodiment, an optimized power converter for use in a transport electrical system that provides power to an electrically powered accessory is provided. The optimized power converter includes an optimized DC/DC converter and an inverter/active rectifier. The optimized DC/DC converter is connected between a rechargeable energy storage of the transport electrical system that provides DC power and the inverter/active rectifier. The optimized DC/DC converter is configured to only boost a voltage level when current is directed from the rechargeable energy storage to the inverter/active rectifier and is configured to only buck a voltage level when current is directed from the inverter/active rectifier to the rechargeable energy storage. The inverter/active rectifier is connected to the optimized DC/DC converter. The optimized power converter is configured to operate in a charging mode and a discharge mode. When the optimized power converter is operating in the charging mode, the inverter/active rectifier is configured to convert three phase AC power into DC power, and the optimized power converter is configured to buck the DC power to a voltage level that is acceptable for charging the rechargeable energy storage. When the optimized power converter is operating in the discharge mode, the optimized DC/DC converter is configured to boost voltage from the rechargeable energy storage, and the inverter/active rectifier is configured to convert boosted DC power into three phase AC power for powering one or more AC loads of the electrically powered accessory.

In a further embodiment, a transport electrical system for powering an electrically powered accessory is provided. The transport electrical system includes an electrically powered accessory load network and an optimized power converter. The electrically powered accessory load network includes a plurality of electrically powered accessory loads that use power to operate the electrically powered accessory. The optimized power converter provides power to one or more electrically powered accessory loads of the electrically powered accessory load network. The optimized power converter includes an optimized DC/DC converter and an inverter/active rectifier. The optimized DC/DC converter is connected between a rechargeable energy storage of the transport electrical system that provides DC power and an inverter/active rectifier. The optimized DC/DC converter is configured to only boost a voltage level when current is directed from the rechargeable energy storage to the inverter/active rectifier and is configured to only buck a voltage level when current is directed from the inverter/active rectifier to the rechargeable energy storage. The inverter/active rectifier is connected to the optimized DC/DC converter. The optimized power converter is configured to operate in a charging mode and a discharge mode. When the optimized power converter is operating in the charging mode, the inverter/active rectifier is configured to convert three phase AC power into DC power, and the optimized power converter is configured to buck the DC power to a voltage level that is acceptable for charging the rechargeable energy storage. When the optimized power converter is operating in the discharge mode, the optimized DC/DC converter is configured to boost voltage from the rechargeable energy storage, and the inverter/active rectifier is configured to convert boosted DC power into three phase AC power for powering the one or more electrically powered accessory loads.

Other features and aspects will become apparent by consideration of the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A illustrates a side view of a van with a transport climate control system, according to one embodiment.

FIG. **1**B illustrates a side view of a truck with a transport climate control system, according to one embodiment.

FIG. **1**C illustrates a perspective view of a climate controlled transport unit, with a transport climate control system, attached to a tractor, according to one embodiment.

FIG. **1**D illustrates a side view of a climate controlled transport unit with a multi-zone transport climate control system, according to one embodiment.

FIG. **1**E illustrates a perspective view of a mass-transit vehicle including a transport climate control system, according to one embodiment.

FIG. **2** illustrates a block diagram schematic of a transport electrical system for powering a transport climate control system, according to one embodiment.

FIGS. **3**A and **3**B illustrate different embodiments of an optimized power converter for charging and discharging a rechargeable energy storage.

FIG. **4** illustrates a schematic diagram of portion of an optimized power converter using multi-phase DC interleaving that is operating as a modified inverter stage, according to one embodiment.

Like reference numbers represent like parts throughout.

DETAILED DESCRIPTION

The embodiments disclosed herein relate to an electrically powered accessory configured to be used with at least one of a vehicle, trailer and a transport container. More particularly, the embodiments disclosed herein relate to a system and method of energy efficient operation of an electrically powered accessory.

It is noted that: U.S. application Ser. No. 16/565,063, "SYSTEM AND METHOD FOR MANAGING POWER AND EFFICIENTLY SOURCING A VARIABLE VOLTAGE FOR A TRANSPORT CLIMATE CONTROL SYSTEM,"; U.S. application Ser. No. 16/565,110, "TRANSPORT CLIMATE CONTROL SYSTEM WITH A SELF-CONFIGURING MATRIX POWER CONVERTER,"; U.S. Provisional Application No. 62/897,833, "OPTIMIZED POWER DISTRIBUTION TO TRANSPORT CLIMATE CONTROL SYSTEMS AMONGST ONE OR MORE ELECTRIC SUPPLY EQUIPMENT STATIONS,"; European Patent Application Number 19382776.3, "PRIORI-

TIZED POWER DELIVERY FOR FACILITATING TRANSPORT CLIMATE CONTROL,"; U.S. application Ser. No. 16/565,205, "TRANSPORT CLIMATE CONTROL SYSTEM WITH AN ACCESSORY POWER DISTRIBUTION UNIT FOR MANAGING TRANSPORT CLIMATE CONTROL ELECTRICALLY POWERED ACCESSORY LOADS,"; U.S. application Ser. No. 16/565,235, "AN INTERFACE SYSTEM FOR CONNECTING A VEHICLE AND A TRANSPORT CLIMATE CONTROL SYSTEM,"; U.S. application Ser. No. 16/565,252, "DEMAND-SIDE POWER DISTRIBUTION MANAGEMENT FOR A PLURALITY OF TRANSPORT CLIMATE CONTROL SYSTEMS,"; and U.S. application Ser. No. 16/565,282, "OPTIMIZED POWER CORD FOR TRANSFERRING POWER TO A TRANSPORT CLIMATE CONTROL SYSTEM,"; all filed concurrently herewith on Sep. 9, 2019, and the contents of which are incorporated herein by reference.

While the embodiments described below illustrate different embodiments of a transport climate control system, it will be appreciated that the electrically powered accessory is not limited to the transport climate control system or a climate control unit (CCU) of the transport climate control system. It will be appreciated that a CCU can be e.g., a transport refrigeration unit (TRU). In other embodiments, the electrically powered accessory can be, for example, a crane attached to a vehicle, a cement mixer attached to a truck, one or more food appliances of a food truck, a boom arm attached to a vehicle, a concrete pumping truck, a refuse truck, a fire truck (with a power driven ladder, pumps, lights, etc.), etc. It will be appreciated that the electrically powered accessory may require continuous operation even when the vehicle's ignition is turned off and/or the vehicle is parked and/or idling and/or charging. The electrically powered accessory can require substantial power to operate and/or continuous and/or autonomous operation (e.g., controlling temperature/humidity/airflow of a climate controlled space) on an as needed basis, independent of the vehicle's operational mode.

FIG. **1**A depicts a climate-controlled van **100** that includes a climate controlled space **105** for carrying cargo and a transport climate control system **110** for providing climate control within the climate controlled space **105**. The transport climate control system **110** includes a climate control unit (CCU) **115** that is mounted to a rooftop **120** of the van **100**. The transport climate control system **110** can include, amongst other components, a climate control circuit (not shown) that connects, for example, a compressor, a condenser, an evaporator and an expansion device to provide climate control within the climate controlled space **105**. It will be appreciated that the embodiments described herein are not limited to climate-controlled vans, but can apply to any type of transport unit (e.g., a truck, a container (such as a container on a flat car, an intermodal container, a marine container, etc.), a box car, a semi-tractor, a bus, or other similar transport unit), etc.

The transport climate control system **110** also includes a programmable climate controller **125** and one or more sensors (not shown) that are configured to measure one or more parameters of the transport climate control system **110** (e.g., an ambient temperature outside of the van **100**, an ambient humidity outside of the van **100**, a compressor suction pressure, a compressor discharge pressure, a supply air temperature of air supplied by the CCU **115** into the climate controlled space **105**, a return air temperature of air returned from the climate controlled space **105** back to the CCU **115**, a humidity within the climate controlled space **105**, etc.) and communicate parameter data to the climate controller **125**. The climate controller **125** is configured to control operation of the transport climate control system **110** including the components of the climate control circuit. The climate controller unit **115** may comprise a single integrated control unit **126** or may comprise a distributed network of climate controller elements **126**, **127**. The number of distributed control elements in a given network can depend upon the particular application of the principles described herein.

The climate-controlled van **100** can also include a vehicle PDU **101**, a VES **102**, a standard charging port **103**, and/or an enhanced charging port **104**. The VES **102** can include a controller (not shown). The vehicle PDU **101** can include a controller (not shown). In one embodiment, the vehicle PDU controller can be a part of the VES controller or vice versa. In one embodiment, power can be distributed from e.g., an electric vehicle supply equipment (EVSE, not shown), via the standard charging port **103**, to the vehicle PDU **101**. Power can also be distributed from the vehicle PDU **101** to an electrical supply equipment (ESE, not shown) and/or to the CCU **115** (see solid lines for power lines and dotted lines for communication lines). In another embodiment, power can be distributed from e.g., an EVSE (not shown), via the enhanced charging port **104**, to an ESE (not shown) and/or to the CCU **115**. The ESE can then distribute power to the vehicle PDU **101** via the standard charging port **103**.

FIG. **1**B depicts a climate-controlled straight truck **130** that includes a climate controlled space **131** for carrying cargo and a transport climate control system **132**. The transport climate control system **132** includes a CCU **133** that is mounted to a front wall **134** of the climate controlled space **131**. The CCU **133** can include, amongst other components, a climate control circuit (not shown) that connects, for example, a compressor, a condenser, an evaporator and an expansion device to provide climate control within the climate controlled space **131**.

The transport climate control system **132** also includes a programmable climate controller **135** and one or more sensors (not shown) that are configured to measure one or more parameters of the transport climate control system **132** (e.g., an ambient temperature outside of the truck **130**, an ambient humidity outside of the truck **130**, a compressor suction pressure, a compressor discharge pressure, a supply air temperature of air supplied by the CCU **133** into the climate controlled space **131**, a return air temperature of air returned from the climate controlled space **131** back to the CCU **133**, a humidity within the climate controlled space **131**, etc.) and communicate parameter data to the climate controller **135**. The climate controller **135** is configured to control operation of the transport climate control system **132** including components of the climate control circuit. The climate controller **135** may comprise a single integrated control unit **136** or may comprise a distributed network of climate controller elements **136**, **137**. The number of distributed control elements in a given network can depend upon the particular application of the principles described herein.

It will be appreciated that similar to the climate-controlled van **100** shown in FIG. **1**A, the climate-controlled straight truck **130** of FIG. **1**B can also include a vehicle PDU (such as the vehicle PDU **101** shown in FIG. **1**A), a VES (such as the VES **102** shown in FIG. **1**A), a standard charging port (such as the standard charging port **103** shown in FIG. **1**A), and/or an enhanced charging port (e.g., the enhanced charging port **104** shown in FIG. **1**A), communicating with and distribute power from/to the corresponding ESE and/or the CCU **133**.

FIG. **1**C illustrates one embodiment of a climate controlled transport unit **140** attached to a tractor **142**. The climate controlled transport unit **140** includes a transport climate control system **145** for a transport unit **150**. The tractor **142** is attached to and is configured to tow the transport unit **150**. The transport unit **150** shown in FIG. **1**C is a trailer.

The transport climate control system **145** includes a CCU **152** that provides environmental control (e.g. temperature, humidity, air quality, etc.) within a climate controlled space **154** of the transport unit **150**. The CCU **152** is disposed on a front wall **157** of the transport unit **150**. In other embodiments, it will be appreciated that the CCU **152** can be disposed, for example, on a rooftop or another wall of the transport unit **150**. The CCU **152** includes a climate control circuit (not shown) that connects, for example, a compressor, a condenser, an evaporator and an expansion device to provide conditioned air within the climate controlled space **154**.

The transport climate control system **145** also includes a programmable climate controller **156** and one or more sensors (not shown) that are configured to measure one or more parameters of the transport climate control system **145** (e.g., an ambient temperature outside of the transport unit **150**, an ambient humidity outside of the transport unit **150**, a compressor suction pressure, a compressor discharge pressure, a supply air temperature of air supplied by the CCU **152** into the climate controlled space **154**, a return air temperature of air returned from the climate controlled space **154** back to the CCU **152**, a humidity within the climate controlled space **154**, etc.) and communicate parameter data to the climate controller **156**. The climate controller **156** is configured to control operation of the transport climate control system **145** including components of the climate control circuit. The climate controller **156** may comprise a single integrated control unit **158** or may comprise a distributed network of climate controller elements **158**, **159**. The number of distributed control elements in a given network can depend upon the particular application of the principles described herein.

In some embodiments, the tractor **142** can include an optional APU **108**. The optional APU **108** can be an electric auxiliary power unit (eAPU). Also, in some embodiments, the tractor **142** can also include a vehicle PDU **101** and a VES **102** (not shown). The APU **108** can provide power to the vehicle PDU **101** for distribution. It will be appreciated that for the connections, solid lines represent power lines and dotted lines represent communication lines. The climate controlled transport unit **140** can include a PDU **121** connecting to power sources (including, for example, an optional solar power source **109**; an optional power source **122** such as Genset, fuel cell, undermount power unit, auxiliary battery pack, etc.; and/or an optional liftgate battery **107**, etc.) of the climate controlled transport unit **140**. The PDU **121** can include a PDU controller (not shown). The PDU controller can be a part of the climate controller **156**. The PDU **121** can distribute power from the power sources of the climate controlled transport unit **140** to e.g., the transport climate control system **145**. The climate controlled transport unit **140** can also include an optional liftgate **106**. The optional liftgate battery **107** can provide power to open and/or close the liftgate **106**.

It will be appreciated that similar to the climate-controlled van **100**, the climate controlled transport unit **140** attached to the tractor **142** of FIG. **1**C can also include a VES (such as the VES **102** shown in FIG. **1**A), a standard charging port (such as the standard charging port **103** shown in FIG. **1**A), and/or an enhanced charging port (such as the enhanced charging port **104** shown in FIG. **1**A), communicating with and distribute power from/to a corresponding ESE and/or the CCU **152**. It will be appreciated that the charging port(s) **103** and/or can be on either the tractor **142** or the trailer. For example, in one embodiment, the standard charging port **103** is on the tractor **142** and the enhanced charging port **104** is on the trailer.

FIG. **1**D illustrates another embodiment of a climate controlled transport unit **160**. The climate controlled transport unit **160** includes a multi-zone transport climate control system (MTCS) **162** for a transport unit **164** that can be towed, for example, by a tractor (not shown). It will be appreciated that the embodiments described herein are not limited to tractor and trailer units, but can apply to any type of transport unit (e.g., a truck, a container (such as a container on a flat car, an intermodal container, a marine container, etc.), a box car, a semi-tractor, a bus, or other similar transport unit), etc.

The MTCS **162** includes a CCU **166** and a plurality of remote units **168** that provide environmental control (e.g. temperature, humidity, air quality, etc.) within a climate controlled space **170** of the transport unit **164**. The climate controlled space **170** can be divided into a plurality of zones **172**. The term "zone" means a part of an area of the climate controlled space **170** separated by walls **174**. The CCU **166** can operate as a host unit and provide climate control within a first zone **172***a* of the climate controlled space **166**. The remote unit **168***a* can provide climate control within a second zone **172***b* of the climate controlled space **170**. The remote unit **168***b* can provide climate control within a third zone **172***c* of the climate controlled space **170**. Accordingly, the MTCS **162** can be used to separately and independently control environmental condition(s) within each of the multiple zones **172** of the climate controlled space **162**.

The CCU **166** is disposed on a front wall **167** of the transport unit **160**. In other embodiments, it will be appreciated that the CCU **166** can be disposed, for example, on a rooftop or another wall of the transport unit **160**. The CCU **166** includes a climate control circuit (not shown) that connects, for example, a compressor, a condenser, an evaporator and an expansion device to provide conditioned air within the climate controlled space **170**. The remote unit **168***a* is disposed on a ceiling **179** within the second zone **172***b* and the remote unit **168***b* is disposed on the ceiling **179** within the third zone **172***c*. Each of the remote units **168***a,b* include an evaporator (not shown) that connects to the rest of the climate control circuit provided in the CCU **166**.

The MTCS **162** also includes a programmable climate controller **180** and one or more sensors (not shown) that are configured to measure one or more parameters of the MTCS **162** (e.g., an ambient temperature outside of the transport unit **164**, an ambient humidity outside of the transport unit **164**, a compressor suction pressure, a compressor discharge pressure, supply air temperatures of air supplied by the CCU **166** and the remote units **168** into each of the zones **172**, return air temperatures of air returned from each of the zones **172** back to the respective CCU **166** or remote unit **168***a* or **168***b*, a humidity within each of the zones **118**, etc.) and communicate parameter data to a climate controller **180**. The climate controller **180** is configured to control operation of the MTCS **162** including components of the climate control circuit. The climate controller **180** may comprise a single integrated control unit **181** or may comprise a distributed network of climate controller elements **181**, **182**. The number of distributed control elements in a given network can depend upon the particular application of the principles described herein.

It will be appreciated that similar to the climate-controlled van **100**, the climate controlled transport unit **160** of FIG. **1**D can also include a vehicle PDU (such as the vehicle PDU **101** shown in FIG. **1**A), a VES (such as the VES **102** shown in FIG. **1**A), a standard charging port (such as the standard charging port **103** shown in FIG. **1**A), and/or an enhanced charging port (e.g., the enhanced charging port **104** shown in FIG. **1**A), communicating with and distribute power from/to the corresponding ESE and/or the CCU **166**.

FIG. **1**E is a perspective view of a vehicle **185** including a transport climate control system **187**, according to one embodiment. The vehicle **185** is a mass-transit bus that can carry passenger(s) (not shown) to one or more destinations. In other embodiments, the vehicle **185** can be a school bus, railway vehicle, subway car, or other commercial vehicle that carries passengers. The vehicle **185** includes a climate controlled space (e.g., passenger compartment) **189** supported that can accommodate a plurality of passengers. The vehicle **185** includes doors **190** that are positioned on a side of the vehicle **185**. In the embodiment shown in FIG. **1**E, a first door **190** is located adjacent to a forward end of the vehicle **185**, and a second door **190** is positioned towards a rearward end of the vehicle **185**. Each door **190** is movable between an open position and a closed position to selectively allow access to the climate controlled space **189**. The transport climate control system **187** includes a CCU **192** attached to a roof **194** of the vehicle **185**.

The CCU **192** includes a climate control circuit (not shown) that connects, for example, a compressor, a condenser, an evaporator and an expansion device to provide conditioned air within the climate controlled space **189**. The transport climate control system **187** also includes a programmable climate controller **195** and one or more sensors (not shown) that are configured to measure one or more parameters of the transport climate control system **187** (e.g., an ambient temperature outside of the vehicle **185**, a space temperature within the climate controlled space **189**, an ambient humidity outside of the vehicle **185**, a space humidity within the climate controlled space **189**, etc.) and communicate parameter data to the climate controller **195**. The climate controller **195** is configured to control operation of the transport climate control system **187** including components of the climate control circuit. The climate controller **195** may comprise a single integrated control unit **196** or may comprise a distributed network of climate controller elements **196**, **197**. The number of distributed control elements in a given network can depend upon the particular application of the principles described herein.

It will be appreciated that similar to the climate-controlled van **100**, the vehicle **185** including a transport climate control system **187** of FIG. **1**E can also include a vehicle PDU (such as the vehicle PDU **101** shown in FIG. **1**A), a VES (such as the VES **102** shown in FIG. **1**A), a standard charging port (such as the standard charging port **103** shown in FIG. **1**A), and/or an enhanced charging port (e.g., the enhanced charging port **104** shown in FIG. **1**A), communicating with and distribute power from/to the corresponding ESE and/or the CCU **192**.

FIG. **2** illustrates a block diagram schematic of one embodiment of a transport electrical system **200** for powering a transport climate control system (e.g., the transport climate control system **110**, **132**, **145**, **162** and **187** shown in FIGS. **1**A-E). The transport electrical system **200** can be provided, for example, in a CCU (e.g., the CCU **115**, **133**, **152**, **166** and **192** shown in FIGS. **1**A-E) to supply electrical power to the CCU. The transport electrical system **200** shown in FIG. **2** is configured to operate with a prime mover powered vehicle. However, it will be appreciated that the transport electrical system **200** can also be configured to operate with an electric vehicle powered by an energy storage device (e.g., one or more batteries) and/or a hybrid vehicle powered by a combination of a prime mover and an energy storage device.

As shown in FIG. **2**, the transport electrical system **200** includes a power bus **202** electrically connecting a power generation network **204**, an auxiliary power network **206**, an external power network **208**, an optimized power converter **240** and a transport climate control load network **212**. It will be appreciated that "regulated" is a term of art. For example, a regulated power supply can convert unregulated AC supply into a constant DC, with the help of a rectifier (or an AC-DC converter, or the like), and can supply a stable voltage (or current in some situations), to a circuit or device that need to be operated within certain power supply limits.

The transport electrical system **200** can manage and regulate energy from one or more energy sources from the power generation network **204**, the auxiliary power network **206** and/or the external power network **208** to the transport climate control load network **212** via the optimized power converter **240**. The one or more energy sources can include a generator **210** and an alternator **205** via the power generation network **204**, an external power **220** (e.g., a utility or shore power source, a commercial charging station, etc.) via the external power network **208**, a rechargeable energy storage **230** via the auxiliary power network **206**. Also, the transport electrical system **200** is configured to supply energy to one or more loads from the transport climate control load network **212**. The loads can be, for example, a compressor **255**, one or more evaporator blowers **265**, one or more condenser fans **270**, a heater **275**, and a controller **260** of a transport climate control system.

The power generation network **204** includes the generator **210**, the alternator **205** and an isolator switch **215** disposed between the alternator **205** and the generator **210** at one end and the power bus **202** at a second end. In some embodiments, the generator **210** can also be used to power components of the transport climate control load network **208**. The generator **210** and the alternator **205** are connected to the power bus **202** via the isolator switch **215**. In one embodiment, the isolator switch **215** can be a switch controlled by the controller **260** that isolates the optimized power converter **240** from receiving energy from the power generation network **204**.

The alternator **205** can be an electrical alternator that can provide AC power to the vehicle. In some embodiments, the alternator **205** can include a rectifier or an AC-DC converter (not shown) that rectifies or converts the AC power to a DC power. The alternator **205** is connected to the power bus **202** via the isolator switch **215**.

It will be appreciated that any type of power source can provide power to the transport electrical system **200** can be part of the power generation network **204**. This can include, for example, the alternator **205**, the generator **210**, a RESS, a generator, an axle-mounted generator, a power take off (PTO) device or ePTO device with an auxiliary converter, etc.

In some embodiments, a voltage sensor (not shown) can be provided in the power generation network **204** to monitor a voltage provided to the power bus **202**. Also, in some embodiments, a current sensor (not shown) can be provided in series with the isolator switch **215** to monitor the current to and from the auxiliary power network **206**.

The external power network **208** includes an external power (e.g., utility power, commercial charging power, etc.) **220** that can provide AC power to the power bus **202**.

The auxiliary power network **206** includes the rechargeable energy storage **230** and two auxiliary power on/off switches **235** disposed between the rechargeable energy storage **230** and the power bus **202**. In some embodiments, the auxiliary power network **206** can be part of the transport climate control system and potentially housed within a transport refrigeration unit. In other embodiments, the auxiliary power network **206** can be external to the transport climate control system and part of the power generation network **204**. In yet some other embodiments, the auxiliary power network **206** can be external to the transport climate control system and external to the power generation network **204**.

In some embodiments, the rechargeable energy storage **230** can include one or more rechargeable batteries (also referred to as hold-over batteries). For example, in one embodiment the rechargeable energy storage **230** can include two auxiliary batteries (not shown). Each of the auxiliary batteries can also be connected to the power bus **202** via the optimized power converter **240**. Also, each of the auxiliary batteries can bypass the optimized power converter **240** and connect to the power bus **202** via one of the auxiliary power on/off switches **235**. It will be appreciated that the rechargeable energy storage **230** can provide sufficient energy to power the transport climate control load network **212** by itself. Each of the auxiliary power on/off switches **235** can be controlled by the controller **260**. In some embodiments, the rechargeable energy storage **230** can be a battery pack.

The optimized power converter **240** is configured to transfer power from one of the power generation network **204**, the external power network **208** and/or the auxiliary power network **206** to the transport climate control load network **212**. In some embodiments, the optimized power converter **240** can be part of an energy management module (e.g., a smart charge module (SCM), etc.). In these embodiments, the optimized power converter **240** can transfer power from the power generation network **204** and/or the external power network **208** to charge one or more rechargeable batteries of the rechargeable energy storage **230**. Thus, the optimized power converter **240** can control current flow along the power bus **202**. In some embodiments, the transport electrical system **200** can include two or more optimized power converters **240** each of which is part of a separate SMC. The optimized power converter **240** is configured to only step-down (buck) voltage of power being sent from the power generation network **204** and/or the external power network **208** to the optimized power converter **240**, and is configured to only step-up (boost) voltage of power from the optimized power converter **240** to various AC load (e.g., the compressor **255**, the heater **275**, the condenser fans **270**, the evaporator fans **265**, the controller **260**, etc.). Accordingly, the optimized power converter **240** can control current direction and current amount along the bus **202**. The optimized power converter **240** is described in further detail with respect to FIGS. **3**A-**4**C.

The transport electrical system **200**, and particularly the optimized power converter **240**, is controlled by the controller **260**. The controller **260** can be, for example, the TRS controller **15** shown in FIG. **1**A, the MTRS controller **170** of FIG. **1**B, or the APU controller **41**. A remote controller **280** can be connected to the controller **260** wirelessly (e.g., Bluetooth, ZigBee, etc.) or via wire (e.g., a communication link such as a RS485 communication link). The remote controller **280** can be located in a cab of the vehicle and can be controlled by a user, for example, a driver. The remote controller **280** can be used by a user to communicate the user's settings for components of the transport climate control load network **212** to the controller **260**.

Components of the transport climate control load network **212** can be, for example, part of a TRU that is mounted to the body of the vehicle (for example, truck). In some embodiments, the TRU can be above the cab of the truck. In another embodiment, the TRU can be on the top of the TU (for example, a top of a box where the external condensers are located). The transport climate control load network **212** includes a compressor **255**, one or more evaporator blowers **265**, one or more condenser fans **270**, the heater **275**, and the controller **260**. The power bus **202** is connected to and powers each of the compressor **255**, the one or more evaporator blowers **265**, the one or more condenser fans **270**, the heater **275**, and the controller **260**.

In some embodiments, the compressor **255** can be a variable speed compressor. In some embodiments, the compressor **255** can require, for example, 1 KW of power to operate. In some embodiments, the one or more evaporator blowers **265** can require, for example, 100 W of power to operate. In some embodiments, the one or more condenser fans **270** can require, for example, 130 W of power to operate. In some embodiments, the heater **275** can require, for example, 1200 W of power to operate.

When the compressor **255** and/or the heater **275** are powered directly by the external power **220**, the compressor **255** and/or the heater **275** can be turned on and off (e.g., operate in a cycle sentry mode) in order to control the amount of cooling provided by the compressor **255** and/or the amount of heating provided by the heater **275**.

FIG. **3**A illustrates a schematic diagram of an optimized power converter **300** for charging and discharging a rechargeable energy storage (e.g., battery pack) **305** (e.g., the rechargeable energy storage **230** shown in FIG. **2**), according to a first embodiment. The optimized power converter **300** includes an accumulation module **307**, an optimized DC/DC converter **310** (e.g., the optimized DC/DC converter **240** shown in FIG. **2**), a DC link **315** and an inverter/active rectifier (also referred to as an active frontend "AFE") **320**. In some embodiments, the optimized power converter **300** can also include an optional voltage stabilization capacitor **325**, and an inductor stage **330**. The optimized power converter **300** can be controlled using a controller (e.g., the controller **260** shown in FIG. **2**). The optimized power converter **300** can be provided in a single circuit.

At one end, the rechargeable energy storage **305** is connected to the accumulation module **307**. The optimized DC/DC converter **310** is connected between the accumulation module **307** and the DC link **315**. The DC link **315** is connected between the optimized DC/DC converter **310** and the inverter/active rectifier **320**. The inverter/active rectifier **320** can then be connected to, for example, a power source and/or one or more AC loads. In the embodiment shown in FIG. **3**A, the inverter/active rectifier **320** can be connected to an external power source **335** (e.g., the external power network **208** shown in FIG. **2**, a commercial charge station, etc.) or a standby machine **340** (e.g., the alternator **205**, the generator **210** shown in FIG. **2**). The inverter/active rectifier **320** can also be connected to one or more AC loads **345** such as, for example, a compressor (e.g., the compressor **255** shown in FIG. **2**), a heater (e.g., the heater **275** shown in

FIG. 2), one or more blowers (e.g., the one or more evaporator blowers **265** shown in FIG. **2**), one or more fans (e.g., the condenser fans **270**, etc.), the controller, etc.

The optimized power converter **300** is configured to operate in a charging mode and a discharge mode. When operating in the charging mode, the optimized power converter **300** is configured to buck a voltage from a power source (e.g., the external power source **335** and/or the standby machine **340**) so that the rechargeable energy storage **305** can be charged. When operating in the discharge mode, the optimized power converter **300** is configured to boost a voltage from the rechargeable energy storage **305** so as to power the one or more AC loads **345**.

The rechargeable energy storage **305** can be, for example, one or more 400 V DC batteries that form a battery pack. It will be appreciated that the voltage of the rechargeable energy storage **305** can vary based on its state of charge. For example, when the rechargeable energy storage **305** includes one or more 400 V DC batteries, the voltage can range between 250 V DC and 420 V DC.

The accumulation module **307** can be, for example, an inductor or a transformer. The accumulation module **307** can be used as a short term energy storage device to assist with DC/DC conversion.

The optimized DC/DC converter **310** has a simplified configuration that controls power flow to and from the rechargeable energy storage **305**. In the charging mode, the optimized DC/DC converter **310** is configured to buck a DC voltage from the DC link **315** to from a DC link voltage level to a rechargeable energy storage voltage level that can be used to charge the rechargeable energy storage **305**. In the discharge mode, the optimized DC/DC converter **310** is configured to boost a DC voltage provided by the rechargeable energy storage **305** from the rechargeable energy storage voltage level to the DC link voltage level and provide the boosted voltage to the DC link **315**. When the rechargeable energy storage **305** is a 400 V DC power source having a rechargeable energy storage voltage level between about 250 V DC to 420 V DC, the DC link voltage level can be about 750 V DC to 800 V DC.

The optimized DC/DC converter **310** includes two switches **312**, **314** that can be switched on and off in order to control power flow to and from the rechargeable energy storage **305**. During the discharge mode, the switches **312**, **314** can be controlled to maintain a constant output voltage to the DC link **315**. During the charging mode, the switches **312**, **314** can be controlled depending on whether the optimized power converter **300** is operating in a constant current mode or a constant voltage mode. In some embodiments, the switches **312**, **314** can be controlled based on a varying duty cycle that can be dependent on, for example, a voltage of the rechargeable energy storage **305**, a current setpoint through the optimized DC/DC converter **310**, a state of charge of the rechargeable energy storage **305**, a voltage of the DC link **315**, etc. It will be appreciated that the switches **312**, **314** can be a Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET), an Insulated Gate Bipolar Transistor (IGBT), or a Bipolar Junction Transistor (BJT), a thyristor, a Gate Turn-Off thyristor (GTO), an Integrated Gate-Commutated Thyristor (IGCT), or the like. As shown in FIG. **3**A, a positive terminal of the rechargeable energy storage **305** is connected to a node of the optimized DC/DC power converter **310** between the two switches **312**, **314**.

When the optimized power converter **300** is configured to operate in the charging mode, the optimized DC/DC converter **310** can operate in a constant current mode and a constant voltage mode. In some embodiments, the controller can control operation of the optimized DC/DC converter **310** in the constant current mode when a state of charge of the rechargeable energy storage **305** is below a charge threshold and in the constant voltage mode when the state of charge of the rechargeable energy storage **305** is above the charge threshold. The charge threshold can be determined based on, for example, the chemistry type of the rechargeable energy storage **305**, a state of health of the rechargeable energy storage **305**, a temperature of the rechargeable energy storage **305**, etc. In some embodiments, the charge threshold can be about 80%. When operating in the constant current mode, the optimized DC/DC converter **310** can more rapidly charge the rechargeable energy storage **305** than when operating in the constant voltage mode. In some embodiments, in the constant current mode the switches **312**, **314** can be controlled using a closed loop pulse width modulation control based on monitoring an output current of the optimized DC/DC converter **310** and based on a slope generated by a difference between an input voltage to the optimized DC/DC converter **310** and an output voltage from the optimized DC/DC converter **310**. When operating in the constant voltage mode, the optimized DC/DC converter **310** can more precisely charge the rechargeable energy storage **305** than when operating in the constant current mode. In some embodiments, in the constant voltage mode the switches **312**, **314** can be controlled using a closed loop pulse width modulation control based on an input voltage to the optimized DC/DC converter **310** and an output filter of the optimized DC/DC converter **310**. Accordingly, the rechargeable energy storage **305** can be charged to a higher state of charge without overcharging and causing damage to the rechargeable energy storage **305**

As opposed to a full bi-directional DC/DC converter that can buck and boost a voltage in both directions, the optimized DC/DC converter **310** is simplified by having only the two switches **312**, **314** in order to only allow the optimized DC/DC converter **310** to boost voltage from the rechargeable energy storage **305** and buck voltage to the rechargeable energy storage **305**. Thus, the optimized DC/DC converter can be manufactured with less components (e.g., two switches **312**, **314** as opposed to four switches) and for a lower price than a full bi-directional DC/DC converter.

The DC link **315** is configured to stabilize and smoothen power transferred between the optimized DC/DC converter **310** and the inverter/active rectifier **320**. The DC link **315** can also prevent transients from passing between the optimized DC/DC converter **310** and the inverter/active rectifier **320**. The DC link **315** shown in FIG. **3**A includes two DC link capacitors **316**, **318** that are connected in parallel with both the optimized DC/DC converter **310** and the inverter/active rectifier **320**. It will be appreciated that in some embodiments, the DC link **315** can include only a single capacitor to replace the two DC link capacitors **316**, **318**.

When the optimized power converter **300** is operating in the charging mode, the inverter/active rectifier **320** is configured to operate as an active rectifier and convert three phase AC power from the power source (e.g., the external power source **335** and/or the standby machine **340**) into DC power that can be transferred to the DC link **315**. When the optimized power converter **300** is operating in the discharge mode, the inverter/active rectifier **320** is configured to operate as an inductor and convert DC power from the DC link **315** into three phase AC power that can be transferred to the one or more AC loads **345**.

The inverter/active rectifier **320** includes three pairs of switches **322***a* and *b*, **324***a* and *b*, and **326***a* and *b*. Each pair of switches **322**, **324**, **326** are connected to separate phase of AC power. For example, when the optimized power converter **300** is operating in the charging mode, each pair of switches **322**, **324**, **326** are connected to a separate phase of the power source (e.g., the external power source **335** and/or the standby machine **340**). When the optimized power converter **300** is operating in the discharge mode, each pair of switches **322**, **324**, **326** provides three phase AC power to one or more AC loads **345**. It will be appreciated that the switches **322**, **324**, **326** can be a MOSFET, IGBT, a BJT, a thyristor, a GTO, an IGCT, or the like. When the rechargeable energy storage **305** is a 400 V DC power source having a rechargeable energy storage voltage level between about 250 V DC to 420 V DC, inverter/active rectifier **320** can convert DC power having a voltage of about 750-800 V DC (i.e., the DC link voltage level) to about 460 V AC power to the one or more AC loads **345**. Also, the inverter/active rectifier **320** can convert three phase AC power having a voltage of about 460 V AC to a DC power having a voltage level of about 750-800 V DC (i.e., the DC link voltage level) that can be provided to the optimized DC/DC converter **310** before being bucked to about a 400 V DC voltage level to recharge the rechargeable energy storage **305**.

In some embodiments, the inductor stage **330** can be positioned between the inverter/active rectifier **320** and one or more of the external power source **335**, the standby machine **340**, and the one or more AC loads **345**. The inductor stage **330** can be a boost inductance to boost a voltage level of the converted three phase AC power from the inverter/active rectifier **320**. When the optimized DC/DC converter **310** is operating in the charging mode, the inductor stage **330** can provide energy storage and can decouple an external power source from the optimized DC/DC converter **310**.

In some embodiments, the optional voltage stabilization capacitor **325** can be positioned between the rechargeable energy storage **305** and the accumulation module **307**. The optional voltage stabilization capacitor **325** is configured to operate as a filter that can stabilize a voltage level of power being transferred from the optimized DC/DC converter **310** to the rechargeable energy storage **305** during a charging mode and can stabilize a voltage level of power being transferred from the rechargeable energy storage **305** to the optimized DC/DC converter **310** during a discharge mode.

In some embodiments, the optimized power converter **300** can be used in ~30 kilowatt applications.

FIG. **3**B illustrates a schematic diagram of an optimized power converter **350** for charging and discharging a rechargeable energy storage (e.g., battery pack) **355**, according to a second embodiment. The optimized power converter **350** can be controlled using a controller (e.g., the controller **260** shown in FIG. **2**). The optimized power converter **350** can be provided in a single circuit. The optimized power converter **350** is similar to the optimized power converter **300** shown in FIG. **3**A, but can be used for larger power applications by using multi-phase DC interleaving between a large application rechargeable energy storage **355** and the inverter/active rectifier **320**. The differences between the optimized power converter **300** and the optimized power converter **350** are discussed in detail below.

As opposed to a single accumulation module **307**, a single optimized DC/DC converter **310**, and a single DC link **315** as provided in the optimized power converter **300** shown in FIG. **3**A, the optimized power converter **350** includes three combinations of accumulation modules **307***a,b,c*, optimized DC/DC converter **310***a,b,c*, and DC links **315***a,b,c* connected in parallel to the rechargeable energy storage **355**. The DC links **315***a,b,c* are connected to an inverter/active rectifier **360** differently than how the DC link **315** is connected to the inverter/active rectifier **320** of the optimized power converter **300**. In particular, a first combination **365***a* of accumulation module **307***a*, optimized DC/DC converter **310***a*, and DC link **315***a* (including a pair of DC link capacitors **316***a*, **318***a*) are all connected as a single DC phase line that is connected to the pair of switches **322***a,b* of the inverter/active rectifier **360**. Similarly, a second combination **365***b* of accumulation module **307***b*, optimized DC/DC converter **310***b*, and DC link **315***b* (including a pair of DC link capacitors **316***b*, **318***b*) are all connected as a single DC phase line that is connected to the pair of switches **324***a,b* of the inverter/active rectifier **360**. Also, a third combination **365***c* of accumulation module **307***c*, optimized DC/DC converter **310***c*, and DC link **315***c* (including a pair of DC link capacitors **316***c*, **318***c*) are all connected as a single DC phase line that is connected to the pair of switches **326***a,b* of the inverter/active rectifier **360**. The optimized power converter **350** can also optionally include three optional voltage stabilization capacitors **325** for each DC phase line. While FIG. **3**B does not explicitly show the circuit configuration of the second combination **365***b* and the third combination **365***c*, it will be appreciated that it is the same as shown with respect to the first combination **365***a*.

Accordingly, when the optimized power converter **350** is operating in the charging mode, each phase of the outputted DC current from the inverter/active rectifier **360** is separated and connected to a separate combination **365** via a separate DC phase line. Thus, when the rechargeable energy storage **355** is a 400 V DC power source having a rechargeable energy storage voltage level between about 250 V DC to 420 V DC, the DC link voltage level can be about 750 V DC to 800 V DC. Also, the inverter/active rectifier **360** can convert DC power having a voltage of about 750-800 V DC (i.e., the DC link voltage level) to about 460 V AC power to the one or more AC loads **345**.

When the optimized power converter **350** is operating in the discharge mode, the current outputted from the rechargeable energy storage **355** is separated into each of the combinations **365***a,b,c* and the DC current output from each of the DC links **315***a,b,c* are sent to a different pair of switches **322**, **324**, **326** of the inverter/active rectifier **360**. Thus, the inverter/active rectifier **360** can convert three phase AC power having a voltage of about 460 V AC to a DC power having a voltage level of about 750-800 V DC (i.e., the DC link voltage level) that can be provided to the optimized DC/DC converter **310** before being bucked to about a 400 V DC voltage level to recharge the rechargeable energy storage **305**.

While the optimized power converter **350** uses multiphase DC interleaving that includes three sets of accumulation modules **307***a,b,c*, optimized DC/DC converter **310***a, b,c*, and DC links **315***a,b,c* connected in parallel to the rechargeable energy storage **355**, it will be appreciated that in other embodiments an optimized power converter can include two phase DC interleaving, or four or more phase DC interleaving.

In some embodiments, the optimized power converter **350** can include an optional high voltage relay **308** that allows a controller to isolate/disconnect the rechargeable energy storage **355** from the optimized power converter **350** when not in operation.

In some embodiments, the optimized power converter **350** can be used in 120 kilowatt-180 kilowatt applications.

Returning to FIG. **3**A, it will be appreciated that the optimized power converter **300** can be limited based on the amount of current that can be sent through the various switches and inductors (e.g., switches **312**, **314**, **322**, **324**, **326** and inductor **307**). Accordingly, the optimized power converter **300** can be used in smaller power applications such as, for example, a transport climate control system for a straight truck application (e.g., the transport climate control system **132** shown in FIG. **1**B), battery holdover applications, etc.

In contrast, the use of multi-phase DC interleaving in the optimized power converter **350** shown in FIG. **3**B allows current to be split through each of the combinations **365***a, b,c*, thereby increasing the current capacity through the optimized power converter **350**. Thus, the optimized power converter **350** has added capability and can be used in larger power applications such as, for example, a transport climate control system for a trailer application (e.g., the transport climate control systems **145** and **162** shown in FIGS. **1**C and **1**D). The use of multi-phase DC interleaving can also reduce electromagnetic interference within the optimized power converter **350**. Also, in some embodiments, the use of multi-phase DC interleaving in the optimized power converter **350** can be used to alternatively operate in the charging mode and the discharge mode by, for example, controlling one or more of the combinations **365** to operate in the charging mode and controlling the other combinations **365** to operate in the discharge mode.

One embodiment of operating in a charging mode and alternatively in a discharge mode through the use of multi-phase DC interleaving is described below with respect to FIG. **4**. In particular, FIG. **4** illustrates a schematic diagram of portion of an optimized power converter using multi-phase DC interleaving (e.g., the optimized power converter **350** shown in FIG. **3**B) that is operating as a modified inverter stage **400**, according to one embodiment. The modified inverter stage **400** is connected to a rechargeable energy storage **405** and an optional voltage stabilization capacitor **425** that are coupled in parallel. An optional high voltage relay **408** can also be provided between the optional voltage stabilization capacitor **425** and the rechargeable energy storage **405**.

The modified inverter stage **400** includes a DC link **415**, an optimized DC/DC converter **410**, and a set of accumulation modules **407***a,b,c*. The DC link **415** is connected to the optimized DC/DC converter **410** and the optimized DC/DC converter **410** is connected to the set of accumulation modules **407***a,b,c*. The DC link **415** can be similar to the DC link **315** shown in FIG. **3**A. In some embodiments, the DC link **415** can include two DC link capacitors (not shown) that are connected in parallel with both the optimized DC/DC converter **410** and an inverter/active rectifier (not shown).

The optimized DC/DC converter **410** includes three pairs of switches **422***a,b*, **424***a,b*, and **426***a,b*. A node **412** between the first pair of switches **422***a,b* is connected to the first accumulation module **407***a* via a first DC phase line **409***a*. Similarly, a node **414** between the second pair of switches **424***a,b* is connected to the second accumulation module **407***b* via a second DC phase line **409***b*. Also, a node **416** between the third pair of switches **426***a,b* is connected to the third accumulation module **407***c* via a third DC phase line **409***c*.

It will be appreciated that the switches **422**, **424**, **426** can be a MOSFET, IGBT, a BJT, a thyristor, a GTO, an IGCT, or the like.

The accumulation modules **407** can be, for example, an inductor or a transformer. The output of the accumulation modules **407** merge together and are connected to the rechargeable energy storage **405**. The output of the accumulation modules **407** can also be connected to the optional voltage stabilization capacitor **425** and the optional high voltage relay **408**.

A positive terminal of the rechargeable energy storage **405** is connected to a node of the optimized DC/DC power converter **410** between the two switches **412**, **414**. Depending on whether the optimized power converter (of which the modified inverter stage **400** is part of) is operating in a charging mode or a discharge mode can determine whether the rechargeable energy storage **405** is receiving power from a power source (e.g., the external power source **335** and/or the standby machine **340**).

A controller (not shown) can control the three pairs of switches **422***a,b*, **424***a,b*, and **426***a,b* to switch and/or alternatively operate between the charging mode and the discharge mode. In particular, the controller can determine when to initiate the charging mode and initiate the discharge mode based on, for example, a status of the DC link **415**, a status of a power source (e.g., the external power source **335** and/or the standby machine **340**), and/or power needs of one or more components of a transport climate control system powered by the optimized power converter. In some embodiments, the controller can control the three pairs of switches **422***a,b*, **424***a,b*, and **426***a,b* using a PWM scheme.

The optional high voltage relay **408** allows a controller to isolate/disconnect the rechargeable energy storage **455** from the optimized power converter (of which the modified inverter stage **400** is part of) when not in operation. The optional voltage stabilization capacitor **425** is configured to operate as a filter that can stabilize a voltage level of power being transferred from the optimized DC/DC converter **410** to the rechargeable energy storage **455** during a charging mode and can stabilize a voltage level of power being transferred from the rechargeable energy storage **455** to the optimized DC/DC converter **410** during a discharge mode.

Aspects:

It will be appreciated that any of aspects 1-8, aspects 9-16, aspects 17-24, and aspects 25-32 can be combined.

Aspect 1. An optimized power converter for use in a transport electrical system that provides power to a transport climate control system, the optimized power converter comprising:

an optimized DC/DC converter connected between a rechargeable energy storage of the transport electrical system that provides DC power and an inverter/active rectifier, wherein the optimized DC/DC converter is configured to only boost a voltage level when current is directed from the rechargeable energy storage to the inverter/active rectifier and is configured to only buck a voltage level when current is directed from the inverter/active rectifier to the rechargeable energy storage; and

the inverter/active rectifier connected to the optimized DC/DC converter,

wherein the optimized power converter is configured to operate in a charging mode and a discharge mode,

wherein when the optimized power converter is operating in the charging mode, the inverter/active rectifier is configured to convert three phase AC power into DC power, and the optimized power converter is configured to buck the DC power to a voltage level that is acceptable for charging the rechargeable energy storage, and

wherein when the optimized power converter is operating in the discharge mode, the optimized DC/DC converter is configured to boost voltage from the rechargeable energy storage, and the inverter/active rectifier is configured to convert boosted DC power into three phase AC power for powering one or more AC loads of the transport climate control system.

Aspect 2. The optimized power converter of aspect 1, further comprising a DC link connected to both the optimized DC/DC converter and the inverter/active rectifier, wherein the DC link stabilizes and smoothens power transferred between the optimized DC/DC converter and the inverter/active rectifier.

Aspect 3. The optimized power converter of any one of aspects 1 and 2, wherein the optimized DC/DC converter includes a first switch, a second switch connected to the first switch, and a node positioned between the first and second switches, and

wherein the a positive terminal of the rechargeable energy storage is connected to the node.

Aspect 4. The optimized power converter of aspect 3, wherein the first switch and the second switch are independently controlled to boost a voltage of current directed from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage.

Aspect 5. The optimized power converter of any one of aspects 1-4, further comprising an accumulation module, with a first end of the accumulation module connected to a positive terminal of the rechargeable energy storage and a second end of the accumulation module connected to the optimized DC/DC converter.

Aspect 6. The optimized power converter of any one of aspects 1-5, further comprising a plurality of accumulation modules, wherein a first end of each of the plurality of accumulation modules is connected to a positive terminal of the rechargeable energy storage,

wherein the optimized DC/DC converter includes:

a first pair of switches, a second pair of switches, and a third pair of switches that are connected in parallel with each other;

a first node positioned in between the first pair of switches, a second node positioned in between the second pair of switches, and a third node positioned between the third pair of switches;

wherein a first accumulation module of the plurality of accumulation modules is connected to the first node via a first DC phase line, a second accumulation module of the plurality of accumulation modules is connected to the second node via a second DC phase line, and a third accumulation module of the plurality of accumulation modules is connected to the third node via a third DC phase line.

Aspect 7. The optimized power converter of aspect 6, wherein the optimized DC/DC converter is configured to send current from the inverter/active rectifier to the rechargeable energy storage via at least one of the first DC phase line, the second DC phase line and the third DC phase line when operating in a charging mode, and send current from the rechargeable energy storage to the inverter/active rectifier via at least another one of the first DC phase line, the second DC phase line and the third DC phase line when operating in a discharge mode.

Aspect 8. The optimized power converter of any one of aspects 6 and 7, wherein each of the first pair of switches are independently controlled to boost a voltage of current directed, via the first DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage,

wherein each of the second pair of switches are independently controlled to boost a voltage of current directed, via the second DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage,

wherein each of the third pair of switches are independently controlled to boost a voltage of current directed, via the third DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage.

Aspect 9. A transport electrical system for powering a transport climate control system, the transport electrical system comprising:

a transport climate control load network that includes a plurality of transport climate control loads that use power to operate the transport climate control system; and

an optimized power converter that provides power to one or more transport climate control loads of the transport climate control load network, the optimized power converter including:

an optimized DC/DC converter connected between a rechargeable energy storage of the transport electrical system that provides DC power and an inverter/active rectifier, wherein the optimized DC/DC converter is configured to only boost a voltage level when current is directed from the rechargeable energy storage to the inverter/active rectifier and is configured to only buck a voltage level when current is directed from the inverter/active rectifier to the rechargeable energy storage, and

the inverter/active rectifier connected to the optimized DC/DC converter,

wherein the optimized power converter is configured to operate in a charging mode and a discharge mode,

wherein when the optimized power converter is operating in the charging mode, the inverter/active rectifier is configured to convert three phase AC power into DC power, and the optimized power converter is configured to buck the DC power to a voltage level that is acceptable for charging the rechargeable energy storage, and

wherein when the optimized power converter is operating in the discharge mode, the optimized DC/DC converter is configured to boost voltage from the rechargeable energy storage, and the inverter/active rectifier is configured to convert boosted DC power into three phase AC power for powering the one or more transport climate control loads.

Aspect 10. The transport electrical system of aspect 9, wherein the optimized power converter includes a DC link connected to the optimized DC/DC converter, wherein the DC link stabilizes and smoothens power transferred between the optimized DC/DC converter and the inverter/active rectifier.

Aspect 11. The transport electrical system of any one of aspects 9 and 10, wherein the optimized DC/DC converter includes a first switch, a second switch connected to the first switch, and a node positioned between the first and second switches, and

wherein the a positive terminal of the rechargeable energy storage is connected to the node.

Aspect 12. The transport electrical system of aspect 11, wherein the first switch and the second switch are independently controlled to boost a voltage of current directed from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage.

Aspect 13. The transport electrical system of any one of aspects 9-12, wherein the optimized power converter includes an accumulation module, with a first end of the accumulation module connected to a positive terminal of the rechargeable energy storage and a second end of the accumulation module connected to the optimized DC/DC converter.

Aspect 14. The transport electrical system of any one of aspects 9-13, wherein the optimized power converter includes a plurality of accumulation modules, wherein a first end of each of the plurality of accumulation modules is connected to a positive terminal of the rechargeable energy storage,

wherein the optimized DC/DC converter includes:

a first pair of switches, a second pair of switches, and a third pair of switches that are connected in parallel with each other;

a first node positioned in between the first pair of switches, a second node positioned in between the second pair of switches, and a third node positioned between the third pair of switches;

wherein a first accumulation module of the plurality of accumulation modules is connected to the first node via a first DC phase line, a second accumulation module of the plurality of accumulation modules is connected to the second node via a second DC phase line, and a third accumulation module of the plurality of accumulation modules is connected to the third node via a third DC phase line.

Aspect 15. The transport electrical system of aspect 14, wherein the optimized DC/DC converter is configured to send current from the inverter/active rectifier to the rechargeable energy storage via at least one of the first DC phase line, the second DC phase line and the third DC phase line when operating in a charging mode, and send current from the rechargeable energy storage to the inverter/active rectifier via at least another one of the first DC phase line, the second DC phase line and the third DC phase line when operating in a discharge mode.

Aspect 16. The transport electrical system of any one of aspects 14 and 15, wherein each of the first pair of switches are independently controlled to boost a voltage of current directed, via the first DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage,

wherein each of the second pair of switches are independently controlled to boost a voltage of current directed, via the second DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage,

wherein each of the third pair of switches are independently controlled to boost a voltage of current directed, via the third DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage.

Aspect 17. An optimized power converter for use in a transport electrical system that provides power to an electrically powered accessory, the optimized power converter comprising:

an optimized DC/DC converter connected between a rechargeable energy storage of the transport electrical system that provides DC power and an inverter/active rectifier, wherein the optimized DC/DC converter is configured to only boost a voltage level when current is directed from the rechargeable energy storage to the inverter/active rectifier and is configured to only buck a voltage level when current is directed from the inverter/active rectifier to the rechargeable energy storage; and

the inverter/active rectifier connected to the optimized DC/DC converter,

wherein the optimized power converter is configured to operate in a charging mode and a discharge mode,

wherein when the optimized power converter is operating in the charging mode, the inverter/active rectifier is configured to convert three phase AC power into DC power, and the optimized power converter is configured to buck the DC power to a voltage level that is acceptable for charging the rechargeable energy storage, and

wherein when the optimized power converter is operating in the discharge mode, the optimized DC/DC converter is configured to boost voltage from the rechargeable energy storage, and the inverter/active rectifier is configured to convert boosted DC power into three phase AC power for powering one or more AC loads of the electrically powered accessory.

Aspect 18. The optimized power converter of aspect 17, further comprising a DC link connected to both the optimized DC/DC converter and the inverter/active rectifier, wherein the DC link stabilizes and smoothens power transferred between the optimized DC/DC converter and the inverter/active rectifier.

Aspect 19. The optimized power converter of any one of aspects 17 and 18, wherein the optimized DC/DC converter includes a first switch, a second switch connected to the first switch, and a node positioned between the first and second switches, and

wherein the a positive terminal of the rechargeable energy storage is connected to the node.

Aspect 20. The optimized power converter of aspect 19, wherein the first switch and the second switch are independently controlled to boost a voltage of current directed from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage.

Aspect 21. The optimized power converter of any one of aspects 17-20, further comprising an accumulation module, with a first end of the accumulation module connected to a positive terminal of the rechargeable energy storage and a second end of the accumulation module connected to the optimized DC/DC converter.

Aspect 22. The optimized power converter of any one of aspects 17-21, further comprising a plurality of accumulation modules, wherein a first end of each of the plurality of accumulation modules is connected to a positive terminal of the rechargeable energy storage,

wherein the optimized DC/DC converter includes:

a first pair of switches, a second pair of switches, and a third pair of switches that are connected in parallel with each other;

a first node positioned in between the first pair of switches, a second node positioned in between the second pair of switches, and a third node positioned between the third pair of switches;

wherein a first accumulation module of the plurality of accumulation modules is connected to the first node via a first DC phase line, a second accumulation module of the plurality of accumulation modules is connected to the second node via a second DC phase line, and a third accumulation module of the plurality of accumulation modules is connected to the third node via a third DC phase line.

Aspect 23. The optimized power converter of aspect 22, wherein the optimized DC/DC converter is configured to send current from the inverter/active rectifier to the rechargeable energy storage via at least one of the first DC phase line, the second DC phase line and the third DC phase line when operating in a charging mode, and send current from the rechargeable energy storage to the inverter/active rectifier via at least another one of the first DC phase line, the second DC phase line and the third DC phase line when operating in a discharge mode.

Aspect 24. The optimized power converter of any one of aspects 22 and 23, wherein each of the first pair of switches are independently controlled to boost a voltage of current directed, via the first DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage,

wherein each of the second pair of switches are independently controlled to boost a voltage of current directed, via the second DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage,

wherein each of the third pair of switches are independently controlled to boost a voltage of current directed, via the third DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage.

Aspect 25. A transport electrical system for powering an electrically powered accessory, the transport electrical system comprising:

an electrically powered accessory load network that includes a plurality of electrically powered accessory loads that use power to operate the electrically powered accessory; and

an optimized power converter that provides power to one or more electrically powered accessory loads of the electrically powered accessory load network, the optimized power converter including:

- an optimized DC/DC converter connected between a rechargeable energy storage of the transport electrical system that provides DC power and an inverter/active rectifier, wherein the optimized DC/DC converter is configured to only boost a voltage level when current is directed from the rechargeable energy storage to the inverter/active rectifier and is configured to only buck a voltage level when current is directed from the inverter/active rectifier to the rechargeable energy storage, and
- the inverter/active rectifier connected to the optimized DC/DC converter,
- wherein the optimized power converter is configured to operate in a charging mode and a discharge mode,
- wherein when the optimized power converter is operating in the charging mode, the inverter/active rectifier is configured to convert three phase AC power into DC power, and the optimized power converter is configured to buck the DC power to a voltage level that is acceptable for charging the rechargeable energy storage, and
- wherein when the optimized power converter is operating in the discharge mode, the optimized DC/DC converter is configured to boost voltage from the rechargeable energy storage, and the inverter/active rectifier is configured to convert boosted DC power into three phase AC power for powering the one or more electrically powered accessory loads.

Aspect 26. The transport electrical system of aspect 25, wherein the optimized power converter includes a DC link connected to the optimized DC/DC converter, wherein the DC link stabilizes and smoothens power transferred between the optimized DC/DC converter and the inverter/active rectifier.

Aspect 27. The transport electrical system of any one of aspects 25 and 26, wherein the optimized DC/DC converter includes a first switch, a second switch connected to the first switch, and a node positioned between the first and second switches, and

wherein the a positive terminal of the rechargeable energy storage is connected to the node.

Aspect 28. The transport electrical system of aspect 27, wherein the first switch and the second switch are independently controlled to boost a voltage of current directed from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage.

Aspect 29. The transport electrical system of any one of aspects 25-28, wherein the optimized power converter includes an accumulation module, with a first end of the accumulation module connected to a positive terminal of the rechargeable energy storage and a second end of the accumulation module connected to the optimized DC/DC converter.

Aspect 30. The transport electrical system of any one of aspects 25-29, wherein the optimized power converter includes a plurality of accumulation modules, wherein a first end of each of the plurality of accumulation modules is connected to a positive terminal of the rechargeable energy storage,

wherein the optimized DC/DC converter includes:

- a first pair of switches, a second pair of switches, and a third pair of switches that are connected in parallel with each other;
- a first node positioned in between the first pair of switches, a second node positioned in between the second pair of switches, and a third node positioned between the third pair of switches;

wherein a first accumulation module of the plurality of accumulation modules is connected to the first node via a first DC phase line, a second accumulation module of the plurality of accumulation modules is connected to the second node via a second DC phase line, and a third accumulation module of the plurality of accumulation modules is connected to the third node via a third DC phase line.

Aspect 31. The transport electrical system of aspect 30, wherein the optimized DC/DC converter is configured to send current from the inverter/active rectifier to the rechargeable energy storage via at least one of the first DC phase line, the second DC phase line and the third DC phase line when operating in a charging mode, and send current from the rechargeable energy storage to the inverter/active rectifier via at least another one of the first DC phase line, the second DC phase line and the third DC phase line when operating in a discharge mode.

Aspect 32. The transport electrical system of any one of aspects 30 and 31, wherein each of the first pair of switches are independently controlled to boost a voltage of current directed, via the first DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage,

wherein each of the second pair of switches are independently controlled to boost a voltage of current directed, via the second DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage,

wherein each of the third pair of switches are independently controlled to boost a voltage of current directed, via the third DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage.

With regard to the foregoing description, it is to be understood that changes may be made in detail, without departing from the scope of the present invention. It is intended that the specification and depicted embodiments are to be considered exemplary only, with a true scope and spirit of the invention being indicated by the broad meaning of the claims.

What is claimed is:

1. An optimized power converter for use in a transport electrical system that provides power to a transport climate control system, the optimized power converter comprising:

an optimized DC/DC converter connected between a rechargeable energy storage of the transport electrical system that provides DC power and an inverter/active rectifier, wherein the optimized DC/DC converter is configured to only boost a voltage level when current is directed from the rechargeable energy storage to the inverter/active rectifier and is configured to only buck a voltage level when current is directed from the inverter/active rectifier to the rechargeable energy storage;

the inverter/active rectifier connected to the optimized DC/DC converter; and

an inductor stage positioned between the inverter/active rectifier and both of a standby machine and one or more AC loads of the transport climate control system, wherein the one or more AC loads of the transport climate control system includes a compressor of a climate control circuit used to provide climate control within a climate controlled space,

wherein the optimized power converter is configured to operate in a charging mode and a discharge mode,

wherein when the optimized power converter is operating in the charging mode, the inverter/active rectifier is configured to convert three phase AC power into DC power, the optimized power converter is configured to buck the DC power to a voltage level that is acceptable for charging the rechargeable energy storage, and the inductor stage is configured to decouple an external power source from the optimized DC/DC converter, and

wherein when the optimized power converter is operating in the discharge mode, the optimized DC/DC converter is configured to boost voltage from the rechargeable energy storage, the inverter/active rectifier is configured to convert boosted DC power into three phase AC power for powering the one or more AC loads of the transport climate control system including the compressor, and the inductor stage is configured to adjust a voltage level of the three phase AC power from the inverter/active rectifier to power the compressor.

2. The optimized power converter of claim **1**, further comprising a DC link connected to the optimized DC/DC converter, wherein the DC link stabilizes and smoothens power transferred between the optimized DC/DC converter and the inverter/active rectifier.

3. The optimized power converter of claim **1**, wherein the optimized DC/DC converter includes a first switch, a second switch connected to the first switch, and a node positioned between the first and second switches, and

wherein a positive terminal of the rechargeable energy storage is connected to the node.

4. The optimized power converter of claim **3**, wherein the first switch and the second switch are independently controlled to boost a voltage of current directed from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage.

5. The optimized power converter of claim **1**, further comprising an accumulation module, with a first end of the accumulation module connected to a positive terminal of the rechargeable energy storage and a second end of the accumulation module connected to the optimized DC/DC converter.

6. The optimized power converter of claim **1**, further comprising a plurality of accumulation modules, wherein a first end of each of the plurality of accumulation modules is connected to a positive terminal of the rechargeable energy storage,

wherein the optimized DC/DC converter includes:

a first pair of switches, a second pair of switches, and a third pair of switches that are connected in parallel with each other;

a first node positioned in between the first pair of switches, a second node positioned in between the second pair of switches, and a third node positioned between the third pair of switches;

wherein a first accumulation module of the plurality of accumulation modules is connected to the first node via a first DC phase line, a second accumulation module of the plurality of accumulation modules is connected to the second node via a second DC phase line, and a third accumulation module of the plurality of accumulation modules is connected to the third node via a third DC phase line.

7. The optimized power converter of claim **6**, wherein the optimized DC/DC converter is configured to send current from the inverter/active rectifier to the rechargeable energy storage via at least one of the first DC phase line, the second DC phase line and the third DC phase line when operating in a charging mode, and send current from the rechargeable energy storage to the inverter/active rectifier via at least another one of the first DC phase line, the second DC phase line and the third DC phase line when operating in a discharge mode.

8. The optimized power converter of claim **6**, wherein each of the first pair of switches are independently controlled to boost a voltage of current directed, via the first DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage,

wherein each of the second pair of switches are independently controlled to boost a voltage of current directed, via the second DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage,

wherein each of the third pair of switches are independently controlled to boost a voltage of current directed, via the third DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage.

9. The optimized power converter of claim 1, wherein the optimized DC/DC converter and the inverter/active rectifier are provided in a single circuit, and

wherein all charging and discharging of the rechargeable energy storage is integrated into the single circuit.

10. The optimized power converter of claim 1, further comprising:

a second optimized DC/DC converter connected between the rechargeable energy storage of the transport electrical system that provides DC power and the inverter/active rectifier, wherein the second optimized DC/DC converter is configured to only boost a voltage level when current is directed from the rechargeable energy storage to the inverter/active rectifier and is configured to only buck a voltage level when current is directed from the inverter/active rectifier to the rechargeable energy storage;

wherein the optimized power converter is configured to provide multi-phase DC interleaving such that:

when the optimized power converter is operating in the charging mode, the inverter/active rectifier is configured to convert three phase AC power into DC power with multiple phases such that a first DC phase line of the DC power is directed to the optimized DC/DC converter and a second DC phase line of the DC power is directed to the second optimized DC/DC converter, and

when the optimized power converter is operating in the discharge mode, current outputted from the rechargeable energy storage is separated and directed to each of the optimized DC/DC converter and the second optimized DC/DC converter.

11. A transport electrical system for powering a transport climate control system, the transport electrical system comprising:

a transport climate control load network that includes a plurality of transport climate control loads that use power to operate the transport climate control system, wherein the plurality of transport climate control loads includes a compressor of a climate control circuit used to provide climate control within a climate controlled space; and

an optimized power converter that provides power to one or more transport climate control loads of the transport climate control load network including the compressor, the optimized power converter including:

an optimized DC/DC converter connected between a rechargeable energy storage of the transport electrical system that provides DC power and an inverter/active rectifier, wherein the optimized DC/DC converter is configured to only boost a voltage level when current is directed from the rechargeable energy storage to the inverter/active rectifier and is configured to only buck a voltage level when current is directed from the inverter/active rectifier to the rechargeable energy storage,

the inverter/active rectifier connected to the optimized DC/DC converter, and

an inductor stage positioned between the inverter/active rectifier and both of a standby machine and the plurality of transport climate control loads,

wherein the optimized power converter is configured to operate in a charging mode and a discharge mode,

wherein when the optimized power converter is operating in the charging mode, the inverter/active rectifier is configured to convert three phase AC power into DC power, the optimized power converter is configured to buck the DC power to a voltage level that is acceptable for charging the rechargeable energy storage, and the inductor stage is configured to decouple an external power source from the optimized DC/DC converter, and

wherein when the optimized power converter is operating in the discharge mode, the optimized DC/DC converter is configured to boost voltage from the rechargeable energy storage, the inverter/active rectifier is configured to convert boosted DC power into three phase AC power for powering the plurality of transport climate control loads including the compressor, and the inductor stage is configured to adjust a voltage level of the three phase AC power from the inverter/active rectifier to power the compressor.

12. The transport electrical system of claim 11, wherein the optimized power converter includes a DC link connected to the optimized DC/DC converter, wherein the DC link stabilizes and smoothens power transferred between the optimized DC/DC converter and the inverter/active rectifier.

13. The transport electrical system of claim 11, wherein the optimized DC/DC converter includes a first switch, a second switch connected to the first switch, and a node positioned between the first and second switches, and

wherein a positive terminal of the rechargeable energy storage is connected to the node.

14. The transport electrical system of claim 13, wherein the first switch and the second switch are independently controlled to boost a voltage of current directed from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage.

15. The transport electrical system of claim 11, wherein the optimized power converter includes an accumulation module, with a first end of the accumulation module connected to a positive terminal of the rechargeable energy storage and a second end of the accumulation module connected to the optimized DC/DC converter.

16. The transport electrical system of claim 11, wherein the optimized power converter includes a plurality of accumulation modules, wherein a first end of each of the plurality of accumulation modules is connected to a positive terminal of the rechargeable energy storage,

wherein the optimized DC/DC converter includes:

a first pair of switches, a second pair of switches, and a third pair of switches that are connected in parallel with each other;

a first node positioned in between the first pair of switches, a second node positioned in between the second pair of switches, and a third node positioned between the third pair of switches;

wherein a first accumulation module of the plurality of accumulation modules is connected to the first node via a first DC phase line, a second accumulation module of the plurality of accumulation modules is connected to the second node via a second DC phase line, and a third accumulation module of the plurality of accumulation modules is connected to the third node via a third DC phase line.

17. The transport electrical system of claim 16, wherein the optimized DC/DC converter is configured to send current from the inverter/active rectifier to the rechargeable energy storage via at least one of the first DC phase line, the second DC phase line and the third DC phase line when operating in a charging mode, and send current from the rechargeable energy storage to the inverter/active rectifier

via at least another one of the first DC phase line, the second DC phase line and the third DC phase line when operating in a discharge mode.

18. The transport electrical system of claim **16**, wherein each of the first pair of switches are independently controlled to boost a voltage of current directed, via the first DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage,

wherein each of the second pair of switches are independently controlled to boost a voltage of current directed, via the second DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage,

wherein each of the third pair of switches are independently controlled to boost a voltage of current directed, via the third DC phase line, from the rechargeable energy storage to the inverter/active rectifier and to buck a voltage of current directed from the inverter/active rectifier to the rechargeable energy storage.

19. The transport electrical system of claim **11**, wherein the optimized DC/DC converter and the inverter/active rectifier are provided in a single circuit, and

wherein all charging and discharging of the rechargeable energy storage is integrated into the single circuit.

20. The transport electrical system of claim **11**, wherein the optimized power converter further includes:

a second optimized DC/DC converter connected between the rechargeable energy storage of the transport electrical system that provides DC power and the inverter/active rectifier, wherein the second optimized DC/DC converter is configured to only boost a voltage level when current is directed from the rechargeable energy storage to the inverter/active rectifier and is configured to only buck a voltage level when current is directed from the inverter/active rectifier to the rechargeable energy storage;

wherein the optimized power converter is configured to provide multi-phase DC interleaving such that:

when the optimized power converter is operating in the charging mode, the inverter/active rectifier is configured to convert three phase AC power into DC power with multiple phases such that a first DC phase line of the DC power is directed to the optimized DC/DC converter and a second DC phase line of the DC power is directed to the second optimized DC/DC converter, and

when the optimized power converter is operating in the discharge mode, current outputted from the rechargeable energy storage is separated and directed to each of the optimized DC/DC converter and the second optimized DC/DC converter.

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